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GROWTH AND DIFFERENTIATION OF THE POSTNATAL VERTEBRA

by

FOLKE KNUTSSON

The individual vertebra constitutes an element of the vertebral column, a structure possessing static and dynamic functions. It is the vertebral bodies, built up into a pillar, that bear the strain, the function of the arches being limited to creating stability by restricting movement. The development of the vertebra is consequently directed by biologic forces analogous to those determining the growth and conformation of the bones of the extremities. The individual vertebra is also a unit in the structure of the spinal canal, which serves as a container for the spinal cord and its nerves and membranes. It is therefore natural that the development of the vertebra is also influenced by the growth of the spinal cord.

As our knowledge of the vertical and horizontal growth of the vertebral body is limited, certain observations made by the author may prove of general interest.

Vertical growth of the vertebral body

Exact figures concerning the growth of the long bones are available from previous investigations. By measuring the distances between various points, marked on the growing bone with metal indicators, it has been possible to

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Fig. 1

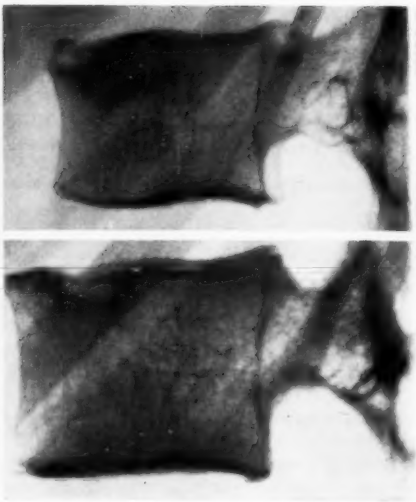


Fig. 2

Fig. 1. Horizontal venous groove (equator) at the middle of the surface of the vertebral body, equidistant from the superior and inferior surfaces of the vertebral body, in a full-grown individual.

Fig. 2. Second lumbar vertebra at 14 and 18 years of age; intracancellous disk prolapse at anterior limbus edge persists as a hollow defect in the latest film. The vertebral body has undergone general growth but the distance between the disk prolapse and posterior edge of the vertebral body remains unchanged. The sagittal growth of the vertebral body has thus taken place only anteriorly.

study the increment in length and arrive at the rate of growth. Corresponding data on the increment in size of the vertebral body, however, do not appear to be available. The embryonic development of this structure is well known but its subsequent growth during childhood and adolescence has never been mapped out in detail. It is accepted that the increase in height takes place in the zone of ossification between the vertebral body and the cartilage plate, i.e. from two different directions, although it is uncertain whether or not the growth from the upper and lower surfaces is uniform.

MOSER has reviewed the investigations that have been carried out in the past with the object of studying the increase in height. The usual method has been to bring about a mechanical or radiation injury to a given area, and then to examine its effect upon growth. The experiments were usually made in animals, and damage inflicted to both the intervertebral cartilage and the two adjacent vertebral body surfaces resulted in inhibition of growth. In his own experiments in pigs, MOSER refined the technique by producing an injury affecting the upper surface of one vertebral body and the under surface of

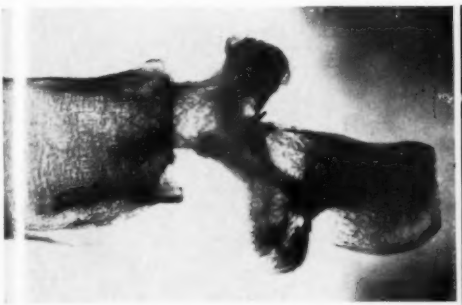


Fig. 3. The position of the dorsal layer of the cortex of the spinal canal is indicated by a metal thread, which in the true lateral view is projected onto the middle of the inferior articular processes. The sagittal diameter of the spinal canal is measured from the posterior surface of the vertebral body to the outline of this layer. (Compare figs 5 and 6.)

Fig. 4. Vertebrae from a case of acromegaly. Periosteal growth takes place chiefly anteriorly but not posteriorly. (From ERDHEIM's work.)

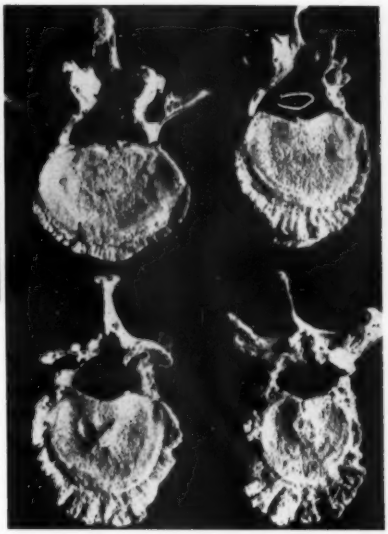


Fig. 4

another. This isolated investigation resulted in inhibition of growth of only that vertebral body of which the upper surface had been damaged. MOSER concluded that the intensity of growth was therefore greater at the upper than the under surface of a vertebra. The final result may hardly be regarded as reliable, however, because it cannot be established that the degree of trauma was equal at both sites. MOSER also examined the thickness of the zones of ossification at the upper and under surfaces in postmortem specimens from children up to 10 years of age, and found that the zones at the upper surfaces were always the thicker. He concluded that this dissimilarity indicates that growth is livelier at the cranial than at the caudal surface.

I would suggest that there is an indication that growth is equal at both upper and under surfaces of the vertebral body. At birth, the lateral roentgenogram reveals a translucent 'equator' encircling the cylindric vertebral body and dividing it into an upper and lower half (Cf. Fig. 5a). The morphology of this 'equator' has been investigated by HANSON who showed it to be a groove containing a venous sinus situated under the perichondrium which, as development proceeds, becomes less and less obvious and finally disappears altogether. HANSON states that it may persist up to 14 years of age. Vestiges of the groove may occasionally be seen in the adult, and in such cases I have found it to lie equidistant from the upper and under surfaces of the vertebral body (Fig. 1);

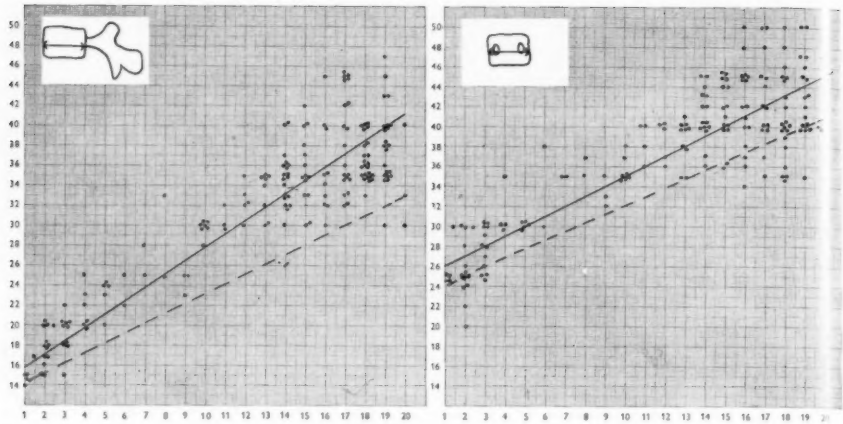
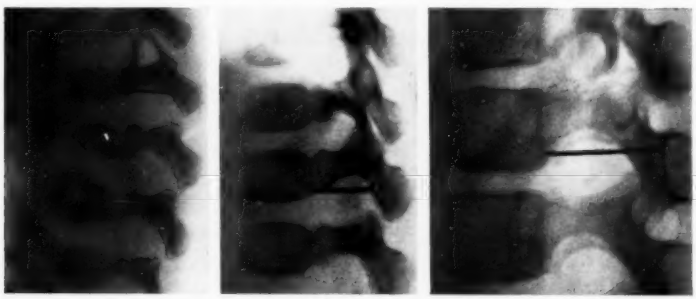


Diagram 1. Frontal and sagittal measurements of the vertebral body in 175 cases. The age in years is given on the abscissa and the size in mm on the ordinate. The continuous lines represent the mean of the values obtained, the interrupted lines the true measurements after approximate correction for enlargement. The vertebral body grows continuously throughout the entire growing period.

the same appearance is apparent in HANSON's illustrations. If growth had been more rapid at the upper surface, as MOSER claims, the groove in the adult ought reasonably to have become displaced towards the lower surface. The matter would appear to require further investigation.

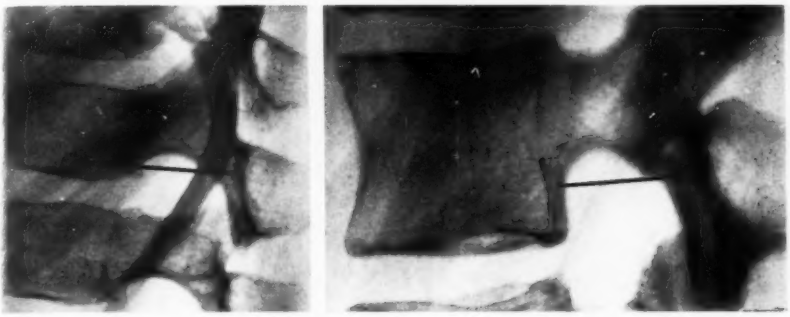
Horizontal growth of the vertebral body

After the completion of endochondral ossification, growth of the vertebral body takes place by means of periosteal apposition, with the interesting feature that it is not equal all around the cylinder but takes place only at the front and



a b c

Fig. 5. Spinal canal at different ages. a) Neonate. b) 3 months. c) 2 years.



a b

Fig. 6. Spinal canal at different ages. a) 3 years. b) 18 years.

sides. In a few cases I have been able to trace the development of a vertebral body by utilizing an unusually early intraspongious disk prolapse as the point of orientation. It was observed that growth was taking place anteriorly but not posteriorly. The case illustrated in Fig. 2 is taken from a previous paper (KNUTSSON). The absence of growth posteriorly towards the spinal canal, with consequent non-encroachment upon its lumen during the course of growth of the vertebral body, may be noted.

In this connexion it is appropriate to consider the periosteal ossification that takes place in acromegaly. ERDHEIM has demonstrated that this condition brings about a continuation of the normal growth process in the vertebral column, the continued periosteal ossification resulting in apposition of new bone to the curved surface of the vertebral body; this additional bone is thickest anteriorly, is slightly thinner on the lateral surfaces, and is absent on the posterior surface (See Fig. 4).

The transverse and sagittal measurements of the body of the first lumbar vertebra were determined from roentgen films of 175 normal individuals aged between 1 and 20 years. The findings are given in Diagram 1. The continuous line represents the mean of the values, the interrupted line, which represents the true measurements, being obtained by making an approximate correction for the enlargement. It will be clear from the diagram that growth takes place continuously throughout childhood and adolescence, as long as the individual is still growing. The vertebral body thus grows in the same manner as the extremities.

Development of the spinal canal

The first lumbar vertebra was again selected for the study of the development of the dimensions of the spinal canal during the growing period, the trans-

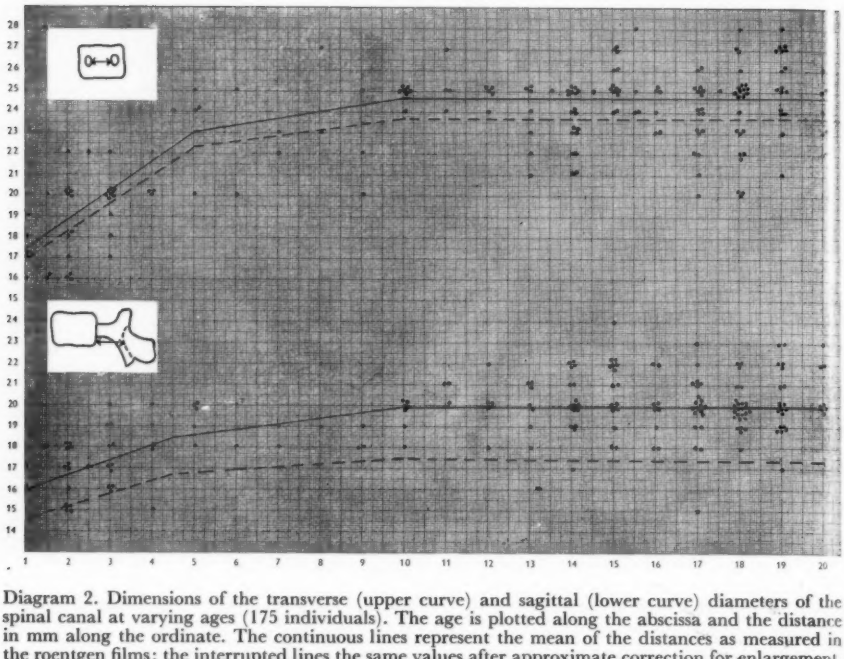


Diagram 2. Dimensions of the transverse (upper curve) and sagittal (lower curve) diameters of the spinal canal at varying ages (175 individuals). The age is plotted along the abscissa and the distance in mm along the ordinate. The continuous lines represent the mean of the distances as measured in the roentgen films; the interrupted lines the same values after approximate correction for enlargement, viz, the true dimensions. The lumen of the spinal canal is already considerable at birth. It increases rapidly in size up to the age of about 5 years, and continues to enlarge slowly up to the age of about 10 years, after when no further increase takes place.

verse and sagittal diameters of the spinal canal being determined from roentgen films of 175 normal individuals of various ages.

The *transverse diameter* of the spinal canal was obtained by measuring the interpedicular space. Similar measurements have been published by FRENCH & PEYTON, SIMRIL & THURSTON, and SCHWARZ. These writers reported the maximum dimensions in a series of normal growing individuals, figures which are required in order to establish the presence of pathologic measurements in the diagnosis of an intraspinal tumour.

The *sagittal diameter* of the spinal canal was determined by measuring the distance between the posterior surface of the vertebral body and the inner cortical layer at the most dorsal part of the arch. This limit is often clearly seen as an arcuate outline in the middle of the superimposed images of the inferior articular processes (Figs 3, 5 and 6).

The measurements obtained of the transverse and sagittal diameters of the

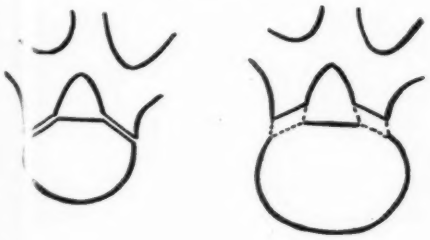


Fig. 7. The growth of the vertebral arch springs from the cartilaginous bridge between it and the vertebral body, the two halves of the arch fusing at the age of 1 to 2 years. Subsequent growth at the cartilaginous joint may result in enlargement of the transverse and sagittal diameters of the spinal canal.

spinal canal are reproduced in Diagram 2. The continuous line is the mean of the individual figures, the interrupted line being the mean of the figures after approximate correction for enlargement. This latter line therefore represents the true measurements, and its course will be an expression of the course of the development of the canal.

The spinal canal is limited by the vertebral body; as explained, the vertebral body, like the extremities, develops continuously throughout the growing period and, as horizontal growth takes place only anteriorly and laterally, the position of the posterior surface is established at birth. It is therefore the growth of the vertebral arch that determines the development of the spinal canal. The growth of the arch springs from the cartilaginous connexion with the vertebral body. The two halves of the arch join by osseous fusion by the first or second year of life when the angle between them is established. The arch may, however, be displaced backwards as a result of further growth at the cartilaginous junction, subsequent extension of the peduncle continuing in the direction of the arch; in this manner the distance between the peduncles and the sagittal diameter of the spinal canal are increased (Fig. 7).

The curves in Diagram 2 show that the dimensions of the spinal canal increase fairly rapidly from birth up to the age of 5 years, and considerably more slowly between 5 and 10 years. The canal is then fully developed and its lumen has reached its adult form. The spinal canal has thus already achieved considerable dimensions at birth and little further increase takes place subsequently. This rate of growth tallies fairly well with the information to be found in the literature, that is, that the growth zone between the vertebral body and the arch gradually fuses during the 3rd to 6th years of life.

It is of interest to compare the growth of the spinal canal with that of the cranial cavity. The rate and pattern of growth of the cranium are determined by the development of the brain. This latter is rapid in the fetus, and during the first 18 months of life, and a correspondingly rapid development of the cranium therefore takes place during this period. After 18 months and up to 14 to 15 years the rate of growth is less (MacRae). The development of the spinal canal is evidently similar to that of the spinal cord. This has already reached a

considerable stage of development at birth, and the lumen of the spinal canal has therefore achieved corresponding dimensions. It continues slowly to widen during the first 5 years of life, and further, very slow, development takes place up to the age of 10 years, when growth is complete.

SUMMARY

The vertical and horizontal growth of the vertebral body is described. It is shown that the development of the spinal canal is determined by the growth of the vertebral arch. It has already reached considerable dimensions at birth, in accord with the early development of the spinal cord.

ZUSAMMENFASSUNG

Das vertikale und horizontale Wachstum des Wirbelkörpers wird beschrieben. Es wird gezeigt, dass die Entwicklung des Rückenmarkskanales durch das Wachstum der Wirbelbögen bestimmt ist und schon bei Geburt ein beträchtliches Ausmass hat. Dieser Umstand stimmt mit der frühen Entwicklung des Rückenmarks überein.

RÉSUMÉ

L'auteur décrit la croissance du corps vertébral dans le sens vertical et dans le sens horizontal. Il montre que le développement du canal rachidien est déterminé par la croissance de l'arc vertébral et qu'il a déjà atteint des dimensions considérables à la naissance, correspondant au développement précoce de la moëlle épinière.

REFERENCES

ERDHEIM, J.: Über Wirbelsäulenveränderungen bei Akromegalie. Virchows Arch. path. Anat. 281 (1931), 197.

FRENCH, L. A. and PEYTON, W. T.: Mixed tumors of spinal canal. Arch. Neurol. Psychiat. 47 (1942), 737.

HANSON, R.: On the development of spinal vertebrae, as seen on skiagrams, from late foetal life to the age of fourteen. Acta radiol. 5 (1926), 112.

KNUTSSON, F.: Observations on the growth of the vertebral body in Scheuermann's disease. Acta radiol. 30 (1948), 97.

MACRAE, D. L.: Die Krampferkrankungen. *In:* Klinische Neuroradiologie, p. 181. Herausgeg. von K. DECKER. Georg Thieme, Stuttgart 1960.

MOSER, H.: Experimentelle Untersuchungen an den Wachstumselementen der Wirbelsäule. *In:* Die Wirbelsäule in Forschung und Praxis. B. 15. Hippokrates-Verlag, Stuttgart 1960.

SCHWARZ, G. S.: The width of the spinal canal in the growing vertebra with special reference to the sacrum. Maximum interpediculate distances in adults and children. Amer. J. Roentgenol. 76 (1956), 476.

SIMRIL, W. A. and THURSTON, D.: The normal interpediculate space in the spines of infants and children. Radiology 64 (1955), 340.

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RELATIONSHIP BETWEEN 'ECCENTRIC CONTRACTIONS' OF THE GALLBLADDER AND THE POST-CHOLECYSTECTOMY SYNDROME

by

LARS ANDRÉN and GEORG THEANDER

ANDRÉN & THEANDER (1958) in a preliminary study of a characteristic type of dynamic deformation of the gallbladder, or 'eccentric contractions', during cholecystography with iopanoic acid (Telepaque) and its sodium salt (Bilijodon-Natrium, or 'Bi-Na'), found the sex and age distribution to resemble that of biliary disease. The deformation occurred in 2 % (12 out of 536 cases) of males and 11 % (90 out of 815 cases) of females examined with Bi-Na, and in the latter most frequently in ages between 30 and 50. The figures were, however, based on observations made exclusively on satisfactorily demonstrated gallbladders containing no stones; this qualification was made to attain a high degree of accuracy, as large or numerous gallbladder stones may obscure the deformation.

The roentgenographic appearances of eccentric gallbladder contractions will not be considered in this communication but an illustrative example is given on next page. The phenomenon has been observed most frequently at examinations with the contrast media mentioned, as well as with Orabilix, but only exceptionally with iodoalphionic acid, Biligrafin and Biligrafin forte. The present study was prompted by the similarity in sex and age distribution of biliary disease and eccentric contractions in examinations with Bi-Na.

It is well known that the abdominal discomfort and pain, often experienced by patients with gallstones and attributed to the biliary system, sometimes

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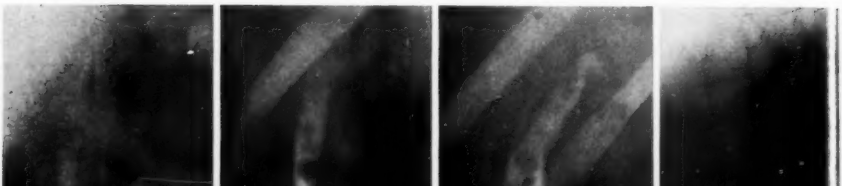

Roentgenograms illustrating 'eccentric contractions' in a gallbladder with stones.

persist after cholecystectomy and removal of any obvious stones from the bile ducts. The condition, generally referred to as the 'post-cholecystectomy syndrome', is widely considered to be due to some dyskinesia of the biliary system. The possible connexion between this syndrome and the occurrence of eccentric gallbladder contractions on preoperative cholecystography was the subject of the present investigation.

Material. The preoperative cholecystograms of 110 cases, in which subsequent cholecystectomy with removal of any obvious stones was performed, were reviewed with special reference to eccentric contractions of the gallbladder. In at least 19 cases, surgery had been followed by complete recovery but, in at least 37 cases, attacks of abdominal pain, probably biliary in origin, had recurred after operation. The postoperative course in these 56 cases had been followed for from one to five years. The course was probably favourable in most of the remaining 54 cases.

Preoperative cholecystography had demonstrated the gallbladder satisfactorily and revealed the presence of gallbladder stones in every case. With few exceptions the examinations had been performed with Bi-Na. Operative and postoperative cholangiography had demonstrated no residual stones. Cholegraphy with Biligrafin forte in cases with recurrence of symptoms had shown no signs of any pathologic condition.

Results and Discussion

The incidence of various degrees of eccentric contractions observed in the preoperative cholecystograms as related to the postoperative course is shown below.

		Eccentric contractions			Total
		Marked	Slight	Absent	
Postoperative course	Post-cholecystectomy syndrome	12	6	19	37
	Probably no symptoms	3	3	48	54
	No symptoms	0	2	17	19
	Total	15	11	84	110

It appears that the phenomenon occurred about four times more frequently in the cases with postoperative symptoms than in those known to have become symptom-free. The incidence observed in the former group, though possibly reduced by the presence of gallbladder stones, far exceeds the highest figure obtained in any series of examinations hitherto on record. This observation is strengthened by the fact that 5 of the 12 cholecystographic examinations, revealing marked eccentric contractions in this group, were performed with iodoalphionic acid, i. e. one of the contrast media least suitable for demonstrating the phenomenon.

In those cases in which the postoperative course was not known with certainty, the observed incidence of eccentric contractions was about the same as in those which had become symptom-free.

The findings suggest a close connection between the post-cholecystectomy syndrome and so-called eccentric contractions of the gallbladder. They thus support the assumption, which is not universally accepted, that biliary disease is responsible for the syndrome and indicate that cases of eccentric contractions of the gallbladder will probably not be relieved by cholecystectomy with removal of all stones.

The physiologic and pathologic mechanisms underlying 'eccentric contractions' of the gallbladder are still obscure. The observations reported strongly suggest that some biliary dyskinesia is reflected by the phenomenon, and further work appears to indicate that the contractions observed are of a passive nature and due to a maladjustment between the size of the gallbladder and the volume of its contents. This point is receiving attention and will be the subject of a future paper.

SUMMARY

A study of preoperative cholecystograms of 110 cases, which had been subjected to cholecystectomy and in which all obvious stones had been removed, revealed that 'eccentric contractions' of the gallbladder were far more common in cases with a post-cholecystectomy syndrome.

ZUSAMMENFASSUNG

Ein Studium praeoperativer Cholezystogramme von 110 cholezystektomierten Fällen, bei denen alle feststellbaren Steine entfernt worden waren, zeigte, dass „exzentrische Kontraktionen" der Gallenblase in Fällen mit einem Post-Cholezystektomie-Syndrom weit häufiger waren.

RÉSUMÉ

L'étude des cholécystographies pré-opératoires de 110 cas, qui ont subi une cholécystectomie et chez lesquels tous les calculs visibles ont été enlevés, a montré que les 'contractions excentriques' de la vésicule biliaire étaient beaucoup plus fréquentes dans les cas qui ont présenté un syndrome post-cholécystectomie.

REFERENCE

ANDRÉN, L. and THEANDER, G.: Eccentric contractions of the gallblader in cholecystography. Acta radiol. 49 (1958), 464.

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TOXICITY OF THE METHYLGLUCAMINE SALT OF TETRA-IODOPHTHALIC ACID MORPHOLIDE

An experimental study in rats

by

Y. EDLUND and L. ZETTERGREN

The evolution of agents for the selective examination of the gallbladder has during recent decades passed from compounds containing one iodine atom bound to an aromatic nucleus to compounds containing three iodine atoms with the same nucleus. This has resulted in the availability of a series of valuable diagnostic contrast media. Compounds containing four iodine atoms in an aromatic ring constitute the next step; a number of these are described in the literature although little is known about their toxic properties.

Investigating the reaction between tetra-iodophthalic acid anhydride and secondary amines, SKAGIUS & EKEMARK prepared the methylglucamine salt of tetra-iodophthalic acid morpholide (Ph 761/3, Pharmacia, Uppsala, Sweden). In rabbits, Ph 761/3 has shown promising properties as a roentgen diagnostic agent for intravenous cholegraphy (NOVEK); it produced a high content of iodine in the biliary flow although most of it was excreted via the kidneys. It was deemed interesting, in the light of these results, to study the action of Ph 761/3 on hepatic and renal tissues.

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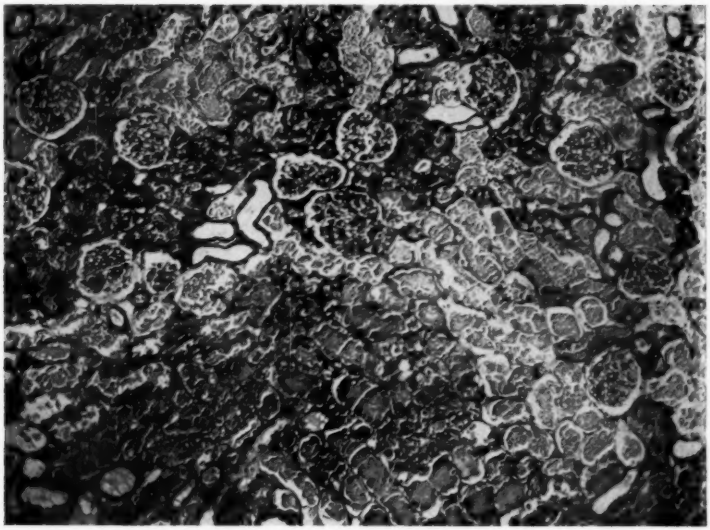

Fig. 1. Kidney with necrotic tubular epithelium. Haematoxylin — van Gieson.

Materials and Methods. The investigation was performed in 29 albino rats belonging to the Sprague-Dawley strain with an average bodyweight of approximately 200 g. Ph 761/3 was administered by the intraperitoneal route in three consecutive daily doses, according to the following schedule:

Dose per 100 g bodyweight	Number of rats
150 mg	5
75 mg	5
37.5 mg	5
30 mg	4
15 mg	5

Three of the rats that were given 150 mg per 100 g bodyweight died the day after the first injection, one on the day following the second injection; a fifth rat was killed two hours after the third injection. All the other rats were decapitated on the fourth day, i. e. the day after the third injection. Five similar rats were used as controls. They received three consecutive daily injections of 0.3 ml physiologic saline per 100 g bodyweight and were decapitated on the fourth day.

The liver and kidneys were excised at necropsy, fixed in formalin 10 %, embedded in paraffin, sectioned, and stained with either haematoxylin — van Gieson or haematoxylin — eosine. A few frozen sections were also prepared and stained with Sudan III.

Fig. 2. Kidney with granular and hyaline casts. Haematoxylin — van Gieson.

Results

Only one of the rats receiving 150 mg Ph 761/3 per 100 g bodyweight was examined post mortem. In this animal, as well as in the five given 75 mg per 100 g bodyweight, the kidneys were pale yellow and flaccid. In the group given 37.5 mg per 100 g bodyweight the kidneys were merely a little paler than normal. In the two remaining test groups as well as in the control group the kidneys were macroscopically unchanged. The liver was of normal appearance in all the groups.

Microscopically the kidneys of rats given doses of Ph 761/3 exceeding 15 mg per 100 g bodyweight exhibited tubular degeneration (nephrosis), the degree of which varied roughly proportionally to the dose of the injected compound. The convoluted tubules were mainly involved and, in severe cases, were completely necrotic (Fig. 1). Granular or hyaline casts were encountered in many of the convoluted tubules (Fig. 2) both in those with destroyed and intact epithelium. Moreover, numerous casts were observed in the medullary collecting tubules in the advanced cases (Fig. 3). No inflammatory changes were evident. In no case were any changes found in the liver.

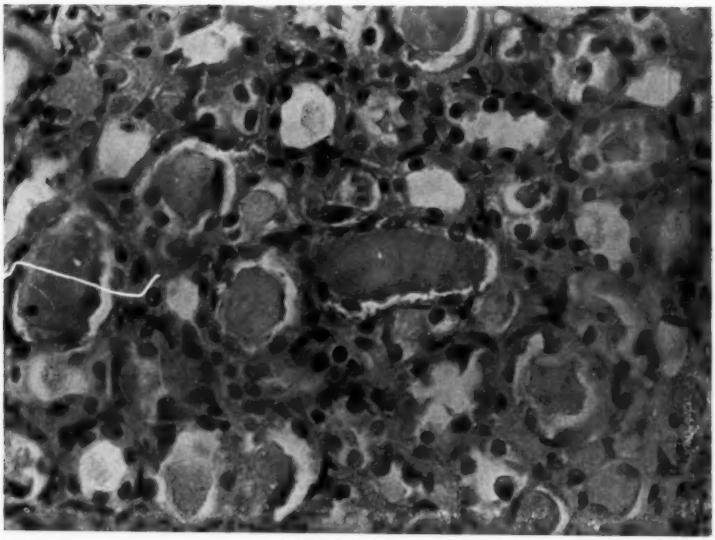

Fig. 3. Kidney with numerous hyaline casts in the collecting tubules. Haematoxylin — van Gieson.

SUMMARY

The toxic properties of a compound, the glucamine salt of tetra-iodophthalic acid morpholide (Ph 761/3), that has shown promising properties as a roentgen diagnostic agent for intravenous cholegraphy in experimental animals, have been tested in 29 albino rats. The effects on the renal and hepatic tissues are described.

ZUSAMMENFASSUNG

Es wurde die Toxicität des Glucaminsalzes von Tetrajodophtalsäuremorpholid (Ph 761/3), die als Diagnostikum für i. v. Cholegraphie im Tierexperiment vielversprechende Eigenschaften zeigte, an 29 Albinoratten getestet. Die Wirkungen auf die Gewebe der Nieren und Leber werden beschrieben.

RÉSUMÉ

Les auteurs ont étudié sur 29 rats albinos la toxicité tétra-iodophthalique morpholide (PH 761/3), qui présente, d'après l'expérimentation animale, des propriétés intéressantes comme moyen de contraste pour la cholégraphie intraveineuse. Ils décrivent les effets sur les tissus hépatique et rénal.

REFERENCES

Novek, Jaan: Excretion in the bile and urine of a biliary tract contrast medium. An experimental study in the rabbit. Acta radiol. 55 (1961), 359.

Skagius, K. and Ekemark, A.: Personal communication (1960).

FROM ROENTGENDIAGNOSTIC DEPARTMENT B (DIRECTOR: DOCENT N. P. G. EDLING), THE DEPARTMENT OF MEDICINE (DIRECTOR: PROF. H. LAGERLÖF) AND THE DEPARTMENT OF RHEUMATOLOGY (DIRECTOR: LABORATOR B. OLHAGEN), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN.

BRANCHIAL ARTERITIS IN THE AORTIC ARCH SYNDROME

A roentgen and differential diagnostic study

by

N. P. G. EDLING, B. NYSTRÖM and S. I. SELDINGER

SAVORY in 1856 published a paper dealing with 'a young woman in whom the main arteries of both upper extremities and of the left side of the neck were throughout completely obliterated'. This was apparently the first report of a disease which later by TAKAYASHU (1908) was suggested as being a pathologic and clinical entity. Comprehensive studies on the subject, including reviews of the literature, have been published among others by ASK-UPMARK (1954), ASK-UPMARK & FAJERS (1956) and KOSZEWSKI (1958). The number of cases which, rightly or wrongly, are reported as examples of the disorder is about 150; about ten of them were confirmed by postmortem examination.

The disease is characterized by a chronic, progressive inflammatory process in the aortic arch as well as in the carotid, subclavian and axillary arteries. The etiology of the disease is unknown. There is panarteritis with round cell infiltration in the periarterial tissues and all layers of the vessel wall. Subsequent thrombosis frequently develops. With few exceptions the condition is reported in young or middle-aged females. The symptoms and signs are both general and local, the former including a high erythrocyte sedimentation rate (ESR)

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and the electrophoretic pattern of the serum proteins showing a slight or moderate increase of gamma globulins and hypoalbuminemia. There is ischaemia in the region where the vascular supply is disturbed. Headache, dizziness, fainting attacks, hemiplegia or aphasia, ocular disturbances, tiredness, and weakness in the arms with pain after exercise, may all occur. Trophic changes in the carotid area with ulcers in the cutaneous tissues and nasal septum may also be seen. The pulsations of the arteries distal to the affected portion are weak or absent. A systolic murmur may be heard in the area of the stenosed arteries.

Many names, such as Takayashu's disease, brachiocephalic arteritis, and pulseless disease have been given to the condition. We shall use none of these for we prefer to term the condition branchial arteritis as suggested by Koszewski; this refers to both the inflammatory character of the disease and the peculiar localization in those arteries, including the aortic arch, which are derived from the embryologic branchial arteries. Only very few exceptions to this localization are described.

From the differential diagnostic point of view branchial arteritis is included in the causes of the 'aortic arch syndrome'. This is a clinical concept applied to the symptomatology found in stenosing processes of one or more of the large branches of the aortic arch, regardless of etiology (Martorell & Fabré 1944, Frövig 1946, Ross & McKusick 1953). For a differentiation of the various causes of the syndrome roentgenologic examinations may be of help. Widened costal grooves have been demonstrated in conventional roentgenograms of the thorax indicating that intercostal arteries serve as collaterals following subclavian artery obstruction (Levin & Rigler 1953, Poker, Finby & Steinberg 1958). Osseous anomalies in the area, usually cervical ribs, may be demonstrated. An examination with a contrast medium is necessary for a more thorough study of the aortic arch with its branches. Thoracic aortography in two cases of branchial arteritis was discussed at some length by Wickbom 1957.

In the present paper we shall discuss the differentiation of disorders which may cause stenosis of the large branches of the aortic arch with special reference to the roentgen diagnosis of branchial arteritis.

Material and Methods

The present series comprises 14 cases of aortic arch syndrome including cases not only with multiple but also with solitary stenosis; a progressive arterial disease with multiple stenoses may give rise to signs of impaired circulation of a single artery. The clinical aspects of 9 of the cases were discussed by Birke, Ejrup & Olhagen (1957), and one of them by Birke & Ekelund (1959).

Conventional roentgenograms of the thorax were obtained in all cases. The arch of the aorta and its main branches were contrast filled in 9 thoracic aortographies after percutaneous catheterization of the right femoral artery

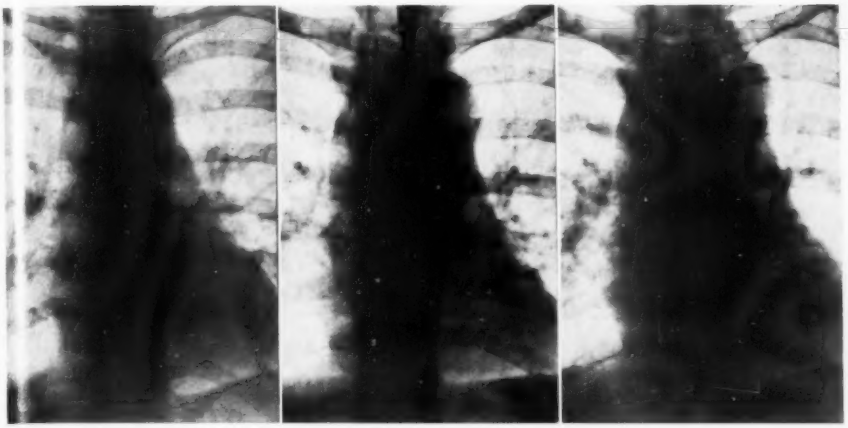

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Fig. 1. Case 1. Branchial arteritis. Heart and thoracic aorta. a) 20 years, normal findings. b) 23 years. c) 27 years. Progressive dilation of the aorta particularly of the ascending and arch portions. d) 23 years. Thoracic aortography. Thickening of wall of distal part of aortic arch (arrows) and irregular narrowing of uppermost part of descending aorta. The summits of the subclavian arteries and, after a short course, the right common carotid artery are occluded. Abnormal origin of markedly narrowed left common carotid artery from innominate artery near the aorta. Vertebral arteries probably normal. Collaterals present. Smooth contours.

in 8 of the cases; in addition, in three of these cases a selective contrast injection into the left subclavian artery was made at the same sitting. Two bilateral, and 4 unilateral arteriographies of the arms as well as one arteriography of the right innominate artery were performed. The femoral artery was examined by one bilateral and two unilateral arteriographies; in one of these the lower part of the abdominal aorta and the iliac arteries were also demonstrated. Thus, in some of the patients, both aortography and peripheral arteriography were performed. The catheterizations were performed by the SELDINGER (1953) and ÖDMAN (1956) methods.

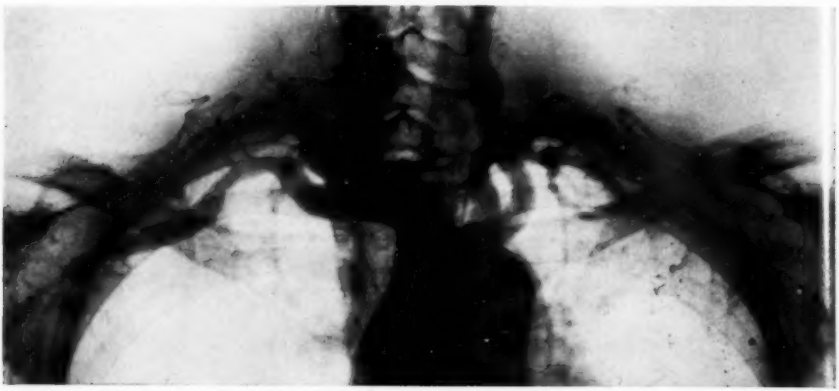

Fig. 2. Case 2. Branchial arteritis. Thoracic aortography. Twisted main branches. Summit of right subclavian, and right axillary and brachial arteries, as well as left subclavian and upper part of axillary artery, irregularly narrowed; remainder of left axillary artery occluded. Carotid and vertebral arteries have smooth lumina. Collaterals present on both sides.

The contrast medium used was a compound of the diatrizoate type (Urografin). For thoracic aortography about 1 ml 60 % medium/kg bodyweight was injected about five centimeters above the aortic ostium. For subclavian arteriography 10 to 20 ml and for iliac-femoral arteriography 20 to 25 ml 45 % medium were used.

No biopsies of the arterial wall were made.

Clinical and roentgenologic observations

All 14 patients had signs of impaired vascular circulation of the arms with pain and rapid exhaustion on exercise, particularly with the arms elevated. They usually complained of cold hands but none of them presented evidence of Raynaud's phenomenon. Oscillography of the arms showed signs of stenosis located centrally in the main arteries. Many of the patients suffered from frequent headaches or dizziness; 4 of them had a history of some major neurologic disturbance such as transient hemiparesis, facial paresis, or aphasia. In 7 of the patients a systolic murmur was heard over a subclavian or carotid artery. All 14 patients obviously had the aortic arch syndrome.

Seven of the patients, all females, had the following additional clinical features in common. The erythrocyte sedimentation rate was elevated and varied from 30 to 135 mm/hour. In the electrophoretic pattern of the serum proteins the gamma globulin was slightly elevated, and there was hypoalbuminemia. There were no signs of stenosing processes in the arteries of the lower extrem-

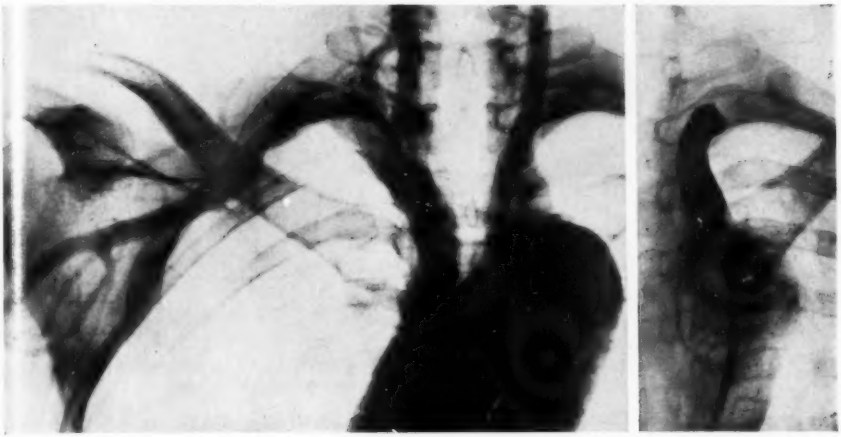

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Fig. 3. Case 4. Branchial arteritis. Thoracic aortography. a) Moderately narrowed lumen of summit of right subclavian artery. First portion of left subclavian artery poorly filled. Smooth contours. Left vertebral artery not filled. b) Selective arteriography of left subclavian artery at same sitting revealed occlusion at the summit. Intercostal collaterals visible.

ities, nor any elevation of the serum cholesterol values; obliteration due to atherosclerosis could therefore reasonably be excluded. No clinical or roentgenologic signs of syphilis were evident. No other explanation to the symptoms but branchial arteritis could be found.

The roentgen findings in the last seven cases were as follows:

Case 1. Female aged 23 years (Fig. 1). The heart was normal in shape and size. Progressive dilatation of the thoracic aorta, particularly of the ascending and arch portions, was observed over a 7-year period of observation. Aortography revealed a thickness of 4 to 5 mm of the upper lateral wall of the distal part of the aortic arch and a slight irregular narrowing, about 5 cm in length, of the upper portion of the descending aorta. The innominate and subclavian arteries had variations in their internal diameters up to the summits where they were occluded. The right common carotid artery was occluded after the course of a few centimeters, and the left arose abnormally from the innominate artery near the aorta and was markedly narrowed. Both vertebral arteries were probably normal; their contours were fairly smooth. Collateral circulation was provided by local arteries in the vicinity of the occlusions as well as by intercostal arteries.

Case 2. Female aged 65. There was relative enlargement of the left ventricle of the heart. The thoracic aorta, particularly the ascending portion, became progressively dilated during a 7 year period of observation. Minute calcium deposits were present in the wall of the arch. Aortography (Fig. 2) showed twisted main branches. The innominate artery had a smooth lumen. The right subclavian artery showed moderate narrowings at the summit, but its distal part was probably normal in width. The axillary artery was considerably narrowed so that its major part and the upper part of the brachial artery had an irregular width of 2 to 4 mm. The

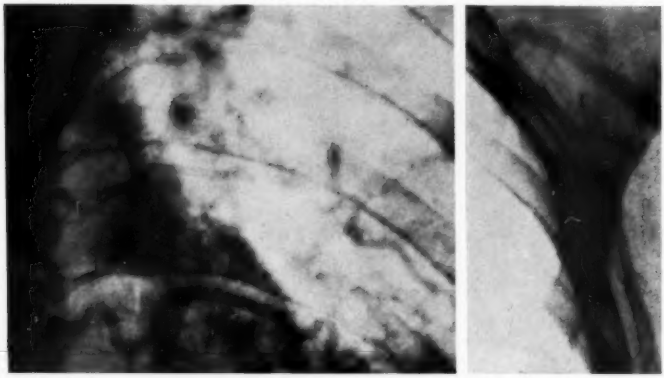

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Fig. 4. Case 4 (same as in fig. 3). Widened left intercostal arteries with notching of ribs. b) Distal part of left axillary artery filled by collateral chest wall arteries.

left subclavian artery was considerably narrowed at the summit and, still narrowed, then continued with slight variations in caliber into the axillary artery; after a short distance this vessel was occluded and collaterals had developed. The common carotid and vertebral arteries were normal in width. The contours in the affected arteries were fairly smooth. Arteriography of the distal part of the aorta and the iliac and femoral arteries revealed no signs of atherosclerosis.

Case 3. Female aged 39. The heart was normal in shape and size. The ascending and arch portions of the thoracic aorta were dilated at 34 years of age. At aortography the innominate artery and the subclavian arteries were seen to be moderately and irregularly narrowed, particularly on the left side. The proximal parts of the axillary arteries were occluded, the distal parts and the proximal parts of the brachial arteries being narrowed with fairly smooth contours. The common carotid and vertebral arteries seemed to be normal. Abundant collaterals along the main stems carried the blood from the aorta to the axillary arteries. The collaterals and the axillary arteries distal to the occlusions were filled before, and better than, the main stems proximal to the occlusions. Intercostal and chest wall collaterals were outlined.

Case 4. Female aged 47. There was relative enlargement of the left ventricle. The thoracic aorta was long and twisted and the ascending and arch portions were dilated (one year's observations). No calcium deposits were visible in the aortic wall. At aortography (Figs 3 and 4) the summit of the right subclavian artery was of irregular width; the remaining parts of the right subclavian artery, the innominate artery and the axillary artery were normal.

The left subclavian artery was abruptly occluded at the summit and the flow was not again seen until the midportion of the axillary artery. This vessel and the upper part of the brachial artery were narrow. Both common carotid arteries and the right vertebral artery were normal; the left vertebral artery was not filled. The contours were smooth. There was a collateral circulation on the left side through local and intercostal arteries, primarily the 8th and 9th, and the chest wall arteries. The former had caused widening of the costal grooves.

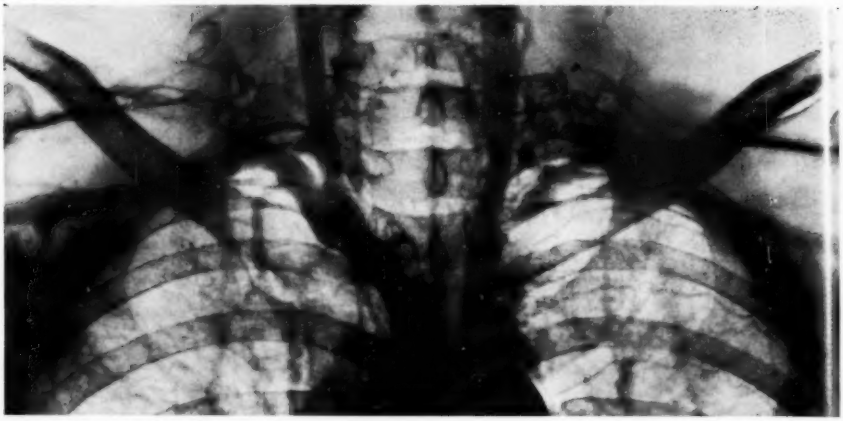
Fig. 5. Case 5. Branchial arteritis. Arteriography of left axillary and brachial arteries after percutaneous puncture of subclavian artery. Smooth narrowing of lumen of axillary artery which is occluded at its junction with the brachial artery. Abundant collaterals, some of which are narrowed.

Case 5. Female aged 34. The heart was normal in shape and size. The thoracic aorta, particularly the ascending portion, became progressively dilated during a 3-year period of observation. At arteriography (Fig. 5) the most distal part of the left subclavian artery and the major part of the axillary artery presented somewhat narrow but smooth lumina. The most distal part of the axillary artery and the uppermost part of the brachial artery were completely occluded 3 to 4 cm distal to a cone-shaped narrowing. In other parts the brachial artery was rather narrow with slight irregular contours. There were abundant collaterals, some of which were also narrowed.

Case 6. Female aged 62. The left ventricle was relatively enlarged. The thoracic aorta was generally widened but without calcifications (one year's observation). At bilateral arteriography the axillary arteries had narrow irregular lumina; the narrowings increased at the junction with the brachial arteries where the lumen was about 1 mm. The brachial arteries were then occluded for 2 and 4.5 cm, respectively, distal to which the lumina became smooth. Collaterals were present mainly at the level of the occlusions. No calcium deposits in the arterial walls of the lower extremities were visible.

Case 7. Female aged 43. The heart was normal in shape and size. The ascending portion of the thoracic aorta was obviously dilated but without calcium deposits (one year's observation). At aortography and selective arteriography of the left subclavian artery the summit of the vessel was markedly narrowed, while the distal part and the axillary artery had long, smooth variations in caliber down to half of the normal; collaterals had developed at the level of the narrowed summit. The first part of the left subclavian artery, the innominate artery, the right subclavian and the common carotid arteries appeared to be normal.

The roentgen findings in the seven cases are summarized in the following. Three of the cases had relative enlargement of the left ventricle of the heart; in the remaining four the heart was normal in shape and size.



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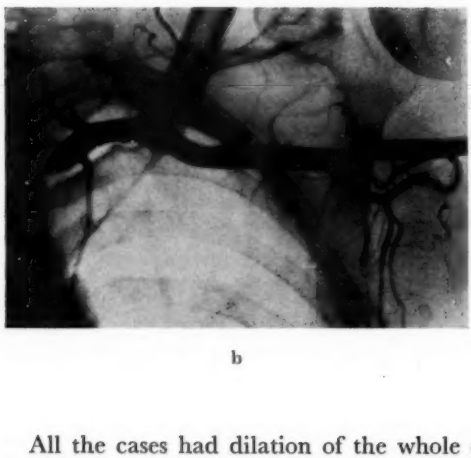

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Fig. 6. Male aged 48. Atherosclerosis. a) Thoracic aortography. Slightly irregular caliber of the right subclavian and axillary arteries. Left subclavian and axillary arteries were not filled so well and appear more narrow. Intercostal arteries on the same side are better shown. b) Arteriography of left subclavian artery. Beginning of artery markedly narrowed, the continuation presenting a slightly irregular lumen. Fairly smooth contours.

All the cases had dilation of the whole or part of the thoracic aorta. In six cases the ascending aorta and the arch of the aorta were mostly affected and in three cases followed up for from 3 to 7 years this dilation was seen to be progressive. One case showed in addition a thickening of the aortic wall and a long moderate narrowing of the uppermost part of the descending aorta. The oldest patient had minute calcium deposits in the wall of the aortic arch although no vascular wall changes were demonstrable at lower lumbar aortography and pelvic-femoral arteriography. In the second oldest patient no calcium deposits were visible in the aorta nor in the vessels of the lower extremities.

The large branches of the aortic arch had in all cases narrowings and occlusions situated in the subclavian and axillary-brachial arteries; in addition, two had

Fig. 7. Female aged 63. Atherosclerosis. Thoracic aortography. Twisted main branches. Right subclavian and axillary arteries with slightly irregular lumen, mostly at the summit; same vessels on left side generally more narrowed and slightly irregular, again mostly at the summit. Metal clips after cervicothoracic sympathectomy to the left.

caliber changes of the innominate artery. One of the cases also had wall changes in both common carotid arteries, and in a further case there was no filling of one vertebral artery.

The narrowings ranged from a slight diminution of caliber to complete occlusion, and the variations occurred in different parts of the vessels, sections of normal width being seen between the narrowings. The contours were completely or fairly smooth and in no case had they the irregularity observed in severe atherosclerosis of the arteries of the lower limb. In the case with changes in the carotid arteries the left one also had an anomalous origin from the initial part of the innominate artery. When marked narrowings and occlusions were present in the vessels to the upper extremities, collaterals had developed; the collaterals were found not only locally but extended through to the intercostal and other thoracic wall arteries. A widening of the costal grooves of 8th and 9th left ribs could be demonstrated in one case.

Reasonable explanations to the impaired circulation in the arms other than branchial arteritis could be offered in all the remaining 7 patients.

The three first, two males and one female, had either roentgenologic evidence of atherosclerosis or oscillographic signs of stenosing processes in the arteries of the lower limbs or both. The two males were 65 and 48 years of age. They had no, or only slight elevation of the ESR, and no changes in the electrophoretic pattern; a branchial arteritis did not seem to explain the clinical picture. Both had a thoracic aorta that was not dilated although in the elder there were some calcifications in the wall of the arch. The beginning of each left subclavian artery was markedly narrowed (Fig. 6) while the continuation had slight narrowings. The right subclavian artery had in one of the two cases slight changes in its wall, while in the second it was

Fig. 8

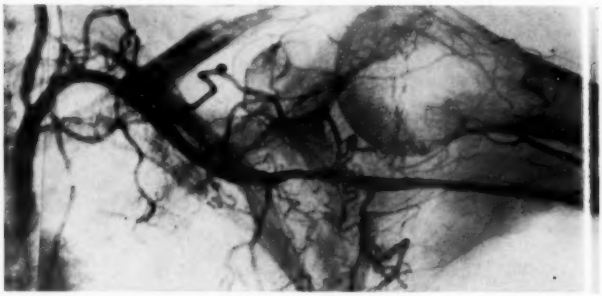

Fig. 9

Fig. 8. Male aged 39. Probably thoracic outlet disorder. Retrograde arteriography of right innominate artery via catheter after percutaneous puncture of common carotid artery (compressed during the injection of contrast medium). Occlusion of subclavian artery, probably due to thrombosis. Normal smooth lumina of innominate and common carotid arteries.

Fig. 9. Female aged 58. Arterial stenosis after extensive roentgen therapy. Arteriography of left subclavian, axillary and brachial arteries after percutaneous catheterization of brachial artery; the arteries are narrowed and vary in caliber. Markedly narrowed region, 1 cm in length, present in axillary artery. Collaterals present.

normal in appearance. The younger patient had extensive, mainly intimal, calcifications of the walls of the arteries of the pelvis and the lower extremities, and right femoral arteriography revealed narrowings of the vessel. The female, 63 years of age, had an elevated ESR; the electrophoretic pattern was only slightly altered. Branchial arteritis could thus not be excluded but the obvious atherosclerosis and repeated respiratory and bladder infections could explain the clinical picture. The case was therefore not placed among those of branchial arteritis. The patient had a dilated thoracic aorta with calcium deposits, and twisted main branches and narrowings of both subclavian and axillary arteries, particularly on the left side (Fig. 7). In the arteries of the lower extremities extensive atherosclerotic changes with calcifications and narrowings were seen at arteriography.

None of these 3 cases revealed wall changes of the common carotid arteries. It may be noted that the contours of the affected subclavian and axillary arteries had not the high degree of irregularity which is often seen in atherosclerosis of the femoral arteries.

In the remaining 4 cases one, a female aged 44, had a fusiformly dilated thoracic portion, and very extensive medial calcifications in the entire thoracic and upper abdominal portions of the aorta. The etiology was obscure; the roentgenologic suggestion of syphilis could not be confirmed clinically. However, the heart was enlarged and, in both supraclavicular regions, apparently dilated, heavily pulsating subclavian arteries were palpated and loud murmurs heard. Retrograde right brachial arteriography revealed occlusions in the axillary and brachial arteries which were otherwise unchanged; collaterals were present. The occlusions were possibly due to embolism, emanating from an aneurysm in the thoracic outlet. A male aged 39, had an occlusion of the right subclavian artery (Fig. 8), and a female aged 38 an occlusion of the distal part of the right axillary artery. Variations in caliber of the distal part of the subclavian artery were also evident in the latter and, in addition, a cervical rib was present on the same side; collaterals had developed. The two last mentioned cases had a normal ESR, and in neither of them were any changes revealed in other contrast filled arteries, nor was any dilation of the aorta found. The female was operated upon twice, and the arterial wall changes and the

cer ical rib confirmed. In the male the cause of the occlusion was not verified but was probably in ne nature of a thoracic outlet disorder with thrombosis of the artery. In the fourth case, a fer ale aged 58 (Fig. 9), the left subclavian, axillary and brachial arteries had in general a sm ller caliber than those on the right side. Narrowings with fairly irregular contours from the sul clavian summit to the uppermost part of the brachial artery were observed. There was a ma ked area of narrowing, about 1 cm in length, in the distal portion of the axillary artery, alt ough a catheter could be passed through it from the brachial artery. Many collaterals we e demonstrated. It was thought that these vascular changes were caused by intimal thicken ngs and shrinkage of the arterial wall and periarterial tissues after roentgen treatment wi n high doses to the supraclavian and axillary glands twenty years previously. There was als atrophy and teleangiectasis of the skin over the areas of the most marked arterial narrow ing. The thoracic aorta was moderately dilated which could be explained by the age of the patient. Branchial arteritis was excluded clinically.

Differential diagnosis

As the local clinical signs in branchial arteritis are not typical but indicate only the site of the arterial stenosis, the differential diagnosis in many cases is difficult. The sex and age of the patient, the history, a careful bedside examination of the peripheral arteries, oscillography of the arms and legs, and laboratory tests such as the ESR, serum protein electrophoresis, Wassermann reaction and serum cholesterol all give valuable clues. Conventional as well as contrast medium examinations of the thorax will afford valuable information regarding the site, extent and degree of the vascular changes. It is our experience that the arterial contrast examination is best done as thoracic aortography after percutaneous catheterization via the femoral artery, preferably combined with selective arteriography of the different arteries at the same sitting (cf. Fig. 3). Direct puncture of the artery proximal to the site of a stenosis (cf. Fig. 5) may be difficult or impossible. The common carotid and the subclavian arteries can, however, often be examined after retrograde percutaneous catheterization as puncture is often possible peripheral to a stenosis, and even to an occlusion, provided sufficient collateral circulation is present; the contrast medium may then be forced against the bloodstream by manual injection (cf. Fig. 9). With most automatic film changers now in use for aortography the dimensions of the films are large enough for demonstrating the arteries at least to the branching of the common carotid arteries, and the upper parts of the brachial arteries. With regard to the possibilities of surgical therapy in cases with localized vascular changes the demonstration of the common carotid and the lower parts of the vertebral arteries is important.

Certain features in conventional films of the thorax may suggest branchial arteritis. The dilation of the proximal parts of the aorta is apparently a common finding although previously not reported. This change is probably caused by a decreased resistance in the wall due to inflammatory infiltration. Its presence in a young female in combination with an unexplained high ESR may suggest the diagnosis and initiate a search for cerebral and ocular disturbances and signs of impaired circulation in the head, neck and arms. A dilation of mainly

the ascending aorta is found also in congenital heart and vessel failures, such as constriction of the aorta and persistent ductus arteriosus. In the majority of these cases the clinical findings and angiocardiograms give a definite diagnosis. If rib notching indicating dilated intercostal arteries is present, constriction of the aorta must be excluded before a stenosing process in the subclavian artery is indicated. It will also be noted that the hereditary disorder of connective tissue, called Marfan's syndrome, may cause progressive dilation of the thoracic aorta. The disease starts in youth, and pregnancy is said to accelerate the dilation. However, this condition is combined with insufficiency of the aortic ostium and enlargement of the left ventricle. A chronic dissecting hematoma (aneurysm) in the aorta is a frequent complication. In the same way, the fusiform aneurysmal widening of the thoracic aorta in syphilis is most often combined with aortic insufficiency and an increase in heart size. The poststenotic dilation in valvular aortic stenosis, and the dilation of the thoracic aorta in hypertension and arteriosclerosis may also be excluded with the help of other clinical and roentgenologic signs.

In addition to dilation of the ascending portion of the aorta and extensive and marked changes in the branchial branches, one of the cases listed as branchial arteritis (cf. Fig. 1) also had thickening of the aortic wall and narrowing of the descending aorta. It seems reasonable to presume that these changes also were caused by the same inflammatory infiltration.

When at contrast medium examination narrowings and occlusions of the branchial arteries are present a roentgenologic diagnosis may again be suggested. However, the findings must be correlated to arteriographic features in other areas as well as to clinical signs.

Congenital vascular anomalies primarily include variations in the origin of the main branches of the aortic arch (cf. Fig. 1), but rarely variations in caliber. Narrowing of the origin of the left subclavian artery may appear when the vessel is in any way involved in a coarctation of the aorta. Congenital anomalies should therefore not be difficult to distinguish from branchial arteritis. On the other hand, abnormal arteries more often than normal ones may be affected by disease.

Other conditions with panarteritis of unknown etiology are thromboangitis obliterans, polyarteritis nodosa, and temporal arteritis. The inflammatory lesions in the first condition involve chiefly medium-sized and small arteries. The distal parts of the extremities, primarily the lower limbs, are involved. Thromboangitis obliterans is a disease which occurs almost exclusively in men under 40 years of age, and is most commonly associated with a superficial phlebitis of the smaller veins. In the case of polyarteritis nodosa mostly minute vessels are affected. There are widely disseminated changes in almost any organ and tissue in the body and this suggests a diffuse systemic process, involving particularly the kidneys, gastrointestinal tract, and peripheral nerves. The incidence among males is greater than among females. Both diseases have

a haracteristic histologic picture. Branchial arteritis is distinguished from th m by its localization, sex distribution, and absence of thrombophlebitis. Te nporal arteritis, although usually situated in branches of the external ca- ro d arteries, may occasionally involve the aortic arch and its main branches, as well as other large or medium-sized arteries (CARDELL & HANLEY 1951). Th e two disorders may therefore have local features in common. However, te nporal arteritis is characterized by an acute-subacute and branchial arteritis by a chronic course, usually for years. This difference is reflected in the serum pr tein pattern, the gamma globulin elevation found in branchial arteritis not be ng present in temporal arteritis. Sex and age distributions are also different, te nporal arteritis mostly affecting the elderly, men and women equally.

Another condition that may cause arterial occlusion is syphilis. However, th s disease usually presents typical serum reactions. Furthermore syphilitic in iltration of the walls of the branchial arteries is very rare and, if present, is part of an aortitis giving clinical signs of aortic insufficiency. Involvement of th e arteries is also a late manifestation of syphilis. The origin of the branches may be occluded by changes in the aortic wall, or by emboli arising from a thrombosed aneurysm. In the presence of an aneurysm conventional roentgenograms may demonstrate the deformity of the thoracic aorta, and aortography will give further information as to the site and size of the aneurysm. One should also bear in mind that syphilitic aortitis predisposes to the development of arteriosclerosis with local calcium deposits.

Atherosclerosis obliterans, in distinction to branchial arteritis, primarily affects the arteries of the lower extremity in subjects of middle or old age. The frequency of atherosclerosis of the branchial branches of the aorta is unfortunately not exactly known. Extensive atherosclerosis of the legs in an elderly subject should suggest changes in the upper aortic branches of a similar nature, at least if the patient has no unexplainable ESR elevation and a normal gamma globulin value. However, atherosclerosis of the larger arteries of the upper extremity must be very uncommon as compared with the lower extremity, because arterial calcifications in this region are very rarely seen in conventional films of the thorax, or in soft tissue films of the upper arms. When present, atherosclerosis seems to have a predilection for the root of the left subclavian artery (ALLEN, BARKER & HINES 1955), which is in agreement with the findings in two of our cases (cf. Fig. 6). In the present atherosclerotic cases the variations in the lumen had fairly smooth contours, and in this respect there was no difference between the atherosclerotic and branchial arteritic cases.

Pseudoxanthoma elasticum is also discussed as a differential diagnostic possibility (BIRKE et coll. 1957). This is a systemic disease of the elastic tissue with typical cutaneous and vascular lesions. Arterial occlusion in the lower extremities appears at an early age. This also occurs in the upper extremities but this location does not seem to be as common (CARLBORG et coll. 1959).

In a case examined by us and reported by BIRKE et coll. and CARLBORG et coll. there were arterial occlusions in the forearm, hand and thigh, but no changes in the brachial and axillary arteries were present.

Arterial embolism is almost always associated with advanced heart disease particularly with auricular fibrillation. The signs of an embolus in the great majority of cases appear suddenly but it is worth noting that they may take several hours to develop.

The shoulder girdle compression syndrome, and the thoracic outlet syndrome are most often combinations of signs referable to the brachial plexus and subclavian vessels, mostly in females. The first syndrome includes cases with normal anatomic thoracic outlets, but the relationship of the structures changes with altered position. The second syndrome includes cases with anatomic abnormalities of the thoracic outlet. In both cases compression of nerves and vessels may appear. In the majority of cases the neurologic signs predominate and the vascular signs are minimal. When the compression of the arteries is prolonged, the vascular walls are damaged, which leads ultimately to occlusion by thrombosis. Emboli may be thrown off from the thrombus to a more distal part of the artery. A careful examination of the arterial pulsations in different positions of the head and arms, and roentgenologic demonstration of anatomic abnormalities such as cervical ribs, may help in the differential diagnosis of the vascular changes as in one of our cases. Arteriography may demonstrate the local stenosis or occlusion, and there may be distal occlusions due to emboli. Other arteries are not involved, in distinction to branchial arteritis, and are therefore not narrowed.

Tumours in the upper mediastinum may displace the actual vessels. However, pulse changes due to their expansion seem to be rare (ROSS & MCKUSICK 1953).

As a last differential diagnostic possibility changes in the walls of the vessels secondary to radiation will be noted. GOTTLOB (1952) has reported one case with narrowings of the pelvic arteries after radiotherapy; postmortem examination revealed perivascular fibrosis and shrinkage. It seems reasonable to presume that similar wall changes were present in our patient.

It is noteworthy in the present series of branchial arteritis that the lesion was, with one exception, restricted to the thoracic aorta and to the subclavian and axillary arteries. This might be due to the fact that no neurologic clinic is served by our roentgen department, and patients with carotid stenosis will probably collect in such clinics. However, it may also possibly indicate that limitation of the disease to the subclavian area is more common than is believed. The arm symptoms are in general milder and less troublesome than the cerebral ones and this may explain why the condition when restricted to the subclavian areas may fail to be recognised until there is greater awareness of the entity. This possibility should therefore be kept in mind when investigating patients with an unexplained elevated ESR, even when no clinical signs of impaired cerebral or ocular circulation are found. Auscultation of stenosed carotid and

subclavian arteries should never be omitted, and any murmur detected should be differentiated from one of cardiac origin.

To sum up, the interpretation of the dilation of the thoracic aorta in conventional films and of narrowings, occlusions and collateral circulations in aortograms or arteriograms in branchial arteritis, should not be difficult. It is much easier to establish the changes than to determine their nature. The exclusion of other conditions and the true diagnosis may not be possible until both the roentgenographic and clinical findings are in acceptable agreement.

SUMMARY

The roentgen and differential diagnoses are discussed in a series of 14 cases of stenosis of the large branches of the aortic arch including 7 cases with signs of branchial arteritis. The difficulty in separating the vascular changes in branchial arteritis from other vascular lesions giving rise to the aortic arch syndrome, particularly atherosclerosis obliterans, is stressed.

ZUSAMMENFASSUNG

Die Röntgendiagnose und die Differentialdiagnostik werden in eine Serie von 14 Fällen mit Stenose der grossen Zweige des Aortabogens diskutiert; das Material enthält 7 Fälle, die Symptome einer branchialen Arteritis zeigten. Die Schwierigkeit, die Gefässveränderungen bei branchialer Arteritis von anderen Gefässveränderungen abzugrenzen, welche Anlass zum Aortabogensyndrom geben, insbesondere der Arteriosklerosis obliterans, wird betont.

RÉSUMÉ

Se fondant sur une série de 14 cas de sténose des grosses branches de la crosse de l'aorte, dont 7 cas présentaient aussi des signes d'artérite branchiale, les auteurs étudient le diagnostic radiologique et différentiel de cette affection. Ils insistent sur la difficulté qu'il y a pour distinguer les altérations vasculaires de l'artérite branchiale d'autres lésions vasculaires donnant un syndrome de la crosse aortique, en particulier l'athérosclerose oblitérante.

REFERENCES

ALLEN, E. V., BARKER, N. W. and HINES, JR, E. A.: Peripheral vascular diseases. 2nd ed. W. B. Saunders, Philadelphia and London 1955.

ASK-UPMARK, E.: On the pulseless disease outside of Japan. Acta med. scand. 149 (1954), 161.

— and FAJERS, C. M.: Further observations on Takayashu's syndrome. Acta med. scand. 155 (1956), 275.

BJERKE, G., EJRUP, B. and OLHAGEN, B.: Pulseless disease. Angiology 8 (1957), 433.

— and EKELUND, L. G.: "Pulseless disease" (Takayashu's syndrome). (In Swedish.) Nord. med. 62 (1959), 1120.

CARDELL, B. S. and HANLEY, T.: Fatal case of giant cell or temporal arteritis. J. Path. Bact. 65 (1951), 587.

CARLBORG, U., EJRUP, B., GRÖNBLAD, E. and LUND, F.: Vascular studies in pseudoxanthoma elasticum and angioid streaks. Acta med. scand. (1959). Suppl. 350.

FROVIG, A. G.: Bilateral obliteration of the common carotid artery. Acta psychiat. scand. (1946) Suppl. 39.

GOTTLOB, R.: Über Strahlenschäden der grossen Blutgefässe. Wien. klin. Wschr. 64 (1952), 361.

KOSZEWSKI, B. J.: Branchial arteritis or aortic arch arteritis. A new inflammatory arterial disease (pulseless disease). Angiology 9 (1958), 180.

LEVIN, B. and RIGLER, L. G.: Rib notching following subclavian artery obstruction. Radiology 62 (1954), 660.

MARTORELL, F. and FABRÉ, T. J.: El sindrome de obliteracion de los troncos supraaorticos. Med clin. (Barcelona) 26 (1944), 17.

ÖDMAN, P.: Percutaneous selective angiography of the main branches of the aorta. Acta radiol. 45 (1956), 1.

— Thoracic aortography by means of a radiopaque polythene catheter inserted percutaneously. Acta radiol. 45 (1956), 117.

POKER, N., FINBY, N. and STEINBERG, I.: The subclavian arteries: roentgen study in health and disease. Amer. J. Roentgenol. 80 (1958), 193.

ROSS, R. S. and MCKUSICK, V. A.: Aortic arch syndromes. Arch. intern. med. 92 (1953), 701.

SAVORY, W. S.: Case of a young woman in whom the main arteries of both upper extremities and of the left side of the neck were throughout completely obliterated. Med. chir. Trans. 39 (1856), 205.

SELDINGER, S. I.: Catheter replacement of the needle in percutaneous arteriography. Acta radiol. 39 (1953), 281.

TAKAYASHU, M.: quoted by ASK-UPMARK and by KOSZEWSKI.

WICKBOM, I.: Arteriography in brachiocephalic arteritis (pulseless disease or the Takayashu syndrome). Acta radiol. 48 (1957), 321.

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SYMÉTRIE DU CRÂNE NORMAL CHEZ LES ADOLESCENTS ET LES ADULTES

par

ANDRÉ THIBAUT

Sur les clichés d'examens complets et faits avec soin, il est généralement facile de reconnaître les asymétries importantes: qu'il s'agisse d'une hypoplasie de la moitié du crâne comme on peut l'observer dans des cas d'atrophie hémisphérique infantile (DAVIDOFF, MASSON, ROSS) par exemple, ou d'un ballonnement plus ou moins important localisé comme dans beaucoup d'hydromes unilatéraux (DAVIDOFF, DYKE, BULL).

Des difficultés surgissent quand il s'agit de reconnaître une asymétrie peu importante et de définir si elle est ou non pathologique. Ce problème de la limite du normal et du pathologique s'est toujours posé au radiologue quelle que soit la région explorée. Ce travail a pour but d'apporter une contribution dans ce domaine en ce qui concerne la morphologie du crâne normal.

Analyse de la littérature. Nous savons par les anatomistes qu'une symétrie parfaite du crâne n'existe que chez 10 à 12 % des individus de l'espèce humaine. Cette constatation est basée sur des mensurations de crânes secs (LEBON). C'est elle qui a conduit TALAIRACH à négliger les points de repères craniens osseux dans ses études stéréotaxiques des formations nerveuses sous-corticales.

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Au point de vue radiologique LEFÈVRE, GUY & METZGER ont étudié la symétrie du crâne chez plusieurs centaines d'enfants normaux et MACRAE chez 56 sujets atteints d'épilepsie non tumorale où l'encéphalographie fractionnée avait montré des signes d'atrophie cérébrale ou corticale de siège et d'étendue variables. Pour leur étude, ces auteurs ont calqué les contours du crâne examiné de face en incidence postéro-antérieure demi-axiale et accessoirement en position antéro-postérieure demi-axiale et axiale. Sur les calques, ils tracent la ligne médiane qu'ils définissent par deux points qui sont le milieu de la gouttière du sinus longitudinal supérieur et le milieu du dos de la selle pour MACRAE, et pour les trois premiers auteurs, le nasion ou l'apophyse odontoïde avec, soit le milieu de la gouttière du sinus longitudinal supérieur, ou le milieu de la suture interpariétale. Ensuite, ils mesurent comparativement le diamètre transversal des deux moitiés du crâne sans préciser toutefois quel point de la voute ils choisissent.

LEFÈVRE, GUY & METZGER ne rapportent pas les détails de leurs observations. Ils concluent à l'existence d'une asymétrie physiologique chez l'enfant normal mais sans en décrire les caractères différentiels d'une asymétrie pathologique. D'ailleurs, ils ne définissent pas ce qu'ils entendent par 'enfant normal'.

Quant à MACRAE, il trouve une asymétrie chez 50 % de ses malades et en fait un signe important dans le tableau radiologique de l'épilepsie non-tumorale. L'asymétrie est légère quand elle dépasse 2 mm, modérée quand elle est comprise entre 2 et 5 mm et importante quand elle dépasse 5 mm. Cependant l'auteur ne spécifie pas les caractéristiques techniques de l'appareillage utilisé pour ces examens. Chez ces mêmes malades il a recherché d'autres manifestations d'asymétrie cranienne, dont le développement inégal des sinus frontaux et des mastoïdes, et aussi le décalage éventuel du bord supérieur des rochers dans le plan vertico-frontal. De l'analyse de ces signes, il résulte que le tableau de l'hypoplasie d'une moitié du crâne comme on le voit dans l'hémi-atrophie cérébrale ne fut qu'exceptionnellement présent. Et pourtant l'auteur ne semble pas faire de distinction entre asymétries et hypoplasies puisqu'en donnant le pourcentage de celles-ci, il cite le pourcentage de celles-là.

La question de savoir s'il y a une différence entre les asymétries 'physiologiques' de LEFÈVRE, GUY & METZGER et les asymétries 'pathologiques' de MACRAE, ne nous paraît pas pouvoir être résolue, faute de définition du sujet normal et d'étude de contrôle chez de pareils sujets. D'ailleurs, la méthode de mensuration utilisée par tous ces auteurs n'est pas satisfaisante. Parce qu'elle est liée au caractère de l'image radiographique, l'appréciation d'une asymétrie est délicate. La moindre rotation de la tête, dans les projections de face, détermine une fausse asymétrie. Il en résulte que tous les examens ne se prêtent pas à des mensurations.

Pour que la projection soit bonne, il faut que le rayon principal soit compris dans le plan médian-sagittal et que celui-ci soit perpendiculaire au plan du film. Mais la difficulté est de matérialiser de façon précise le plan médian-

sagittal sur le crâne à radiographier. Beaucoup de méthodes ont été préconisées (Fürcher, Ledoux-Lebar, Olsson). Cependant, quel que soit l'artifice utilisé, c'est finalement sur le film que l'on peut juger de la perfection de la position de la tête et du centrage.

Si le rayon principal, perpendiculaire au plan du film, est effectivement compris dans le plan médian-sagittal du crâne, tous les points médians repérés sur le cliché peuvent être réunis l'un à l'autre et se trouvent sur une même droite. Si une droite définie par deux d'entre-eux passe par un troisième, la projection est parfaite. Jackson utilise le lambda, le bregma et le nasion. Ces trois points sont parmi les points médians décrits par les anthropologistes (Broca); malheureusement, ils ne sont pas toujours repérables en ce qui concerne le lambda et le bregma tandis que le nasion est très difficile à identifier sur les clichés de face.

Jackson considère les mensurations inutiles ou peu utiles pour distinguer les asymétries normales des asymétries pathologiques. Il signale que les asymétries pathologiques se manifestent non seulement par des modifications de volume mais aussi par d'autres signes morphologiques qui permettent bien souvent de préjuger de leur cause étant donné nos connaissances sur la croissance des os du crâne et leurs réactions aux agents mécaniques. Cette opinion est basée sur ses propres observations de plusieurs cas d'asymétrie pathologique de nature différente et sur les travaux d'autres auteurs dont Childe, Bull, Hardman & Jupe.

Ces autres signes morphologiques consistent en modifications de l'épaisseur de la voûte, du relief de la thèque interne, de la pneumatisation des cavités sinusales paranasales et des mastoïdes.

Cependant, Lombardi a rapporté l'observation d'un cas où l'encéphalographie fractionnée et l'artériographie carotidienne furent normales alors que l'examen direct avait montré une asymétrie du crâne associée à d'autres signes morphologiques réalisant un tableau semblable à celui rencontré dans certains hydromes ou hématomes sous-duraux chroniques juvéniles (Bull, Thibaut).

Cette observation a un grand intérêt. Elle permet de penser (en dehors d'autres hypothèses, par exemple une fausse asymétrie) que l'association de modifications morphologiques convergentes ne suffit pas pour donner un caractère pathologique à une asymétrie du crâne et qu'un facteur quantitatif caractérisant aussi bien l'importance de l'asymétrie que celle des modifications morphologiques associées peut constituer un élément déterminant dans le diagnostic différentiel.

Matériel. Nous considérons qu'une asymétrie pathologique traduit par définition une modification du contenu de la boîte cranienne. Dès lors, nous avons retenu comme critère du crâne normal l'intégrité anatomique macroscopique de son contenu.

C'est donc sur une base anatomique que nous avons sélectionné notre ma-

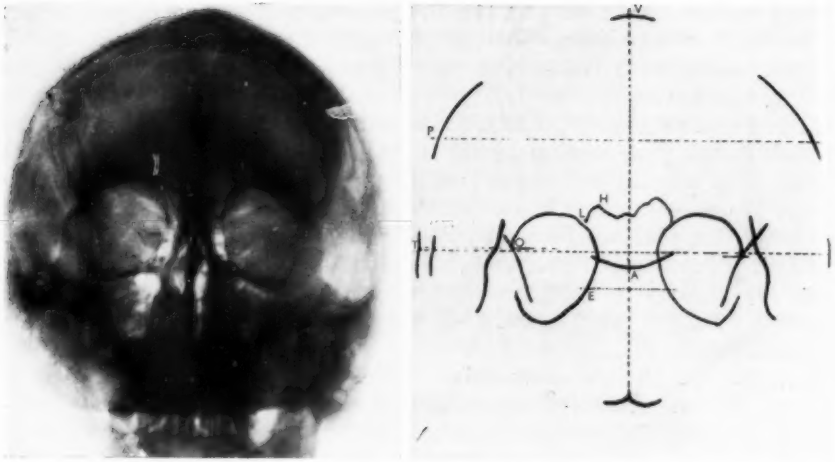

Fig. 1. Repères utilisés pour les mensurations en incidence postéro-antérieure demi-axiale.

A — Point d'intersection de la ligne de l'étage antérieur avec la ligne médiane.
V — Point le plus haut du contour externe de la voûte, sur la ligne médiane.
O — Point d'intersection de la ligne de la grande aile du sphénoïde avec le contour interne de la paroi supéro-externe de l'orbite.
P — Point du contour externe de la voûte situé sur la perpendiculaire élevée de la ligne médiane en un point situé à mi-distance entre A et V.
T — Point du contour externe de la voûte situé sur une perpendiculaire à la ligne médiane passant à hauteur des points 0 (bien souvent ces deux points ne sont pas à la même hauteur, dans ce cas la perpendiculaire passe entre les deux).
H — Point le plus élevé du sinus frontal.
L — Point le plus externe du sinus frontal.
E — Point du contour externe de l'ethmoïde situé sur une perpendiculaire élevée de la ligne médiane, 10 mm en dessous du point A.

tériel en postulant que là où l'encéphalographie fractionnée avait été négative, c'est-à-dire avait montré l'absence de tout déplacement, déformation ou dilatation du système ventriculaire et des espaces sous-arachnoïdiens, le contenu du crâne était normal. Cependant, comme ce travail a été entrepris aussi pour servir de base à l'étude de la symétrie du crâne dans l'épilepsie non tumorale (Ruggiero, Thibaut, Hecaen & Dell 1960) nous n'avons retenu dans notre matériel que les malades non épileptiques. Leur âge varie entre 15 et 50 ans.

Cent examens ont été étudiés. Tous avaient été jugés suffisants pour les besoins cliniques et considérés comme négatifs avec l'optique de routine habituelle.

Chaque examen comporte au moins quatre incidences: profil, face postéro-antérieure demi-axiale, antéro-postérieure demi-axiale et axiale.

Tous ont été réalisé au craniographe de Lysholm, avec un foyer d'une surface de 2 mm/2 mm et à la distance focale de 70 cm.

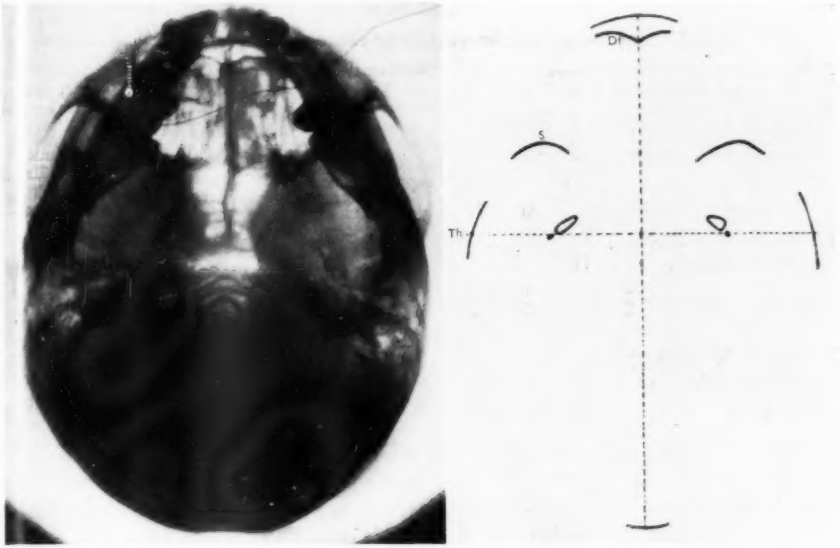

Fig. 2. Repères utilisés pour les mensurations en incidence axiale.

S — Point le plus antérieur du contour antérieur de la grande aile du sphénoïde.
Th — Point du contour externe de la voûte situé sur une perpendiculaire à la ligne médiane passant à hauteur des trous petits ronds.
Df — Point situé sur le contour postérieur du sinus frontal 10 mm en dehors de la ligne médiane.

Pour chaque cas, nous avons revu les clichés en projection axiale et postéro-antérieure demi-axiale en vue de mensurations et recherché sur les quatre clichés de chaque examen l'existence éventuelle de petits signes de développement asymétrique de caractère plus morphologique que volumétrique.

Technique de mensurations. Nous avons utilisé un négatoscope à lumière très intense de manière à bien distinguer les contours osseux et un papier transparent millimètré que nous avons appliqué et fixé sur les clichés à l'aide de pinces métalliques.

Les points médians que nous avons choisis sont: le bregma, le lambda, la base de la cloison médiane du nez, le milieu du nasion, la faux ou l'épiphyse calcifiée et, sur la suture interpariétale, un point quelconque situé sur un segment de droite réunissant les points d'inversion de la courbe sinusoïde dessinée par les incisures de la suture. Tous les clichés où trois de ces points n'ont pu être repérés et ceux où, repérés et réunis, trois points médians ne se trouvaient pas sur une même droite, ont été éliminés.

Tableau 1

Caractères des asymétries unilatérales observées sur l'incidence postéro-antérieure demi-axiale

Nombre de cas selon le siège et le côté de la réduction transversale				Nombre des cas où l'épaisseur de la voûte est plus grande, égale ou moindre du côté réduit par rapport à l'autre			Nombre de cas où le développement des sinus est plus marqué, égal ou moindre du côté réduit par rapport à l'autre					
							Sinus frontaux			Sinus éthmoïdaux		
Siège		G	D	+	=	—	+	=	—	+	=	—
Réduction d'un diamètre seulement	17											
P	9	6	3	2	4	3	1	4	4	7	0	2
T	8	5	3	1	3	4	3	3	2	2	3	3
Réduction des deux diamètres (P et T)	42	18	24	6	24	12	7	21	14	15	6	21
Total	59	29	30	9	31	19	11	28	20	24	9	26

Dans les 100 cas, 68 avaient un cliché en incidence de face postéro-antérieure demi-axiale mesurable, 68 un cliché en incidence axiale et 50 des clichés mesurables dans les deux incidences.

Sur le papier calque, nous avons tracé la ligne médiane, ainsi qu'un certain nombre de points choisis arbitrairement pour nos mesures (Figs 1 et 2). Nous avons mesuré la distance séparant les points P, T, et Th de la ligne médiane et nous avons calculé la différence d'un côté par rapport à l'autre. En P, le diamètre transversal correspond à celui de la région pariétale, en T et Th, de deux régions différentes de la fosse temporale. En ce qui concerne les points S, nous avons mesuré leur décalage dans le plan horizontal. Ce décalage indique que la grande aile du sphénoïde est plus saillante vers l'avant d'un côté sans traduire nécessairement une différence de diamètre antéro-postérieur des fosses temporales, mais quand il coïncide avec une différence dans le même sens d'un ou des deux diamètres transversaux de la région temporale, nous avons admis que les fosses temporales étaient asymétriques. Ensuite, nous avons mesuré l'épaisseur de la voûte à hauteur du point T et calculé les différences des deux côtés.

Enfin, par les mesures des écarts entre les points H, L, Df et E, nous avons voulu objectiver les asymétries de développement des cavités sinusales paranasales. Cette méthode est évidemment imprécise mais schématise les éléments sur lesquels nous nous basons pour dire qu'un sinus est plus développé d'un côté que de l'autre. Elle n'est pas appliquée pour comparer le développement des apophyses mastoïdes que nous avons étudié à part avec d'autres aspects morphologiques que peuvent revêtir les asymétries du crâne.

Tableau 2

Caractères des asymétries unilatérales observées sur l'incidence axiale

Siège	Nombre de cas selon le siège et le côté de la réduction	G	D	Nombre de cas où la profondeur du sinus frontal est plus grande, égale ou moindre du côté réduit par rapport à l'autre +	=	—
Réduction isolée du diamètre Th	8	6	2	6	2	0
Existence isolée d'un décalage postérieur de S	10	7	3	5	3	2
Association d'une réduction du diamètre Th et d'un décalage postérieur de S	34	23	11	11	8	15
Total	52	36	16	22	13	17

Les asymétries observées sur l'incidence de face postéro-antérieure demi-axiale. Sur les 68 examens, les diamètres transversaux sont symétriques dans 3 cas. Dans les 65 autres cas, une asymétrie transversale est présente. Elle est de type alterne dans 6 cas, c'est-à-dire que le diamètre temporal est réduit d'un côté et le diamètre pariétal du côté opposé. Enfin, dans les 59 cas restants l'asymétrie est unilatérale, portant sur un ou les deux diamètres à la fois; nous en avons rapporté les caractères dans le Tableau 1.

Les asymétries observées sur l'incidence axiale. Sur les 68 examens, dans 5 cas, les points Th et S sont symétriques. Dans les 63 autres cas, il existe une asymétrie. Dans 11 cas, elle est de type alterne, le diamètre transversal étant réduit d'un côté tandis que de l'autre côté, la grande aile du sphénoïde est moins saillante vers l'avant. Enfin, dans les 52 cas restants, l'asymétrie est unilatérale et se manifeste soit par l'existence isolée d'une réduction du diamètre transversal ou d'une saillie moins marquée vers l'avant de la grande aile du sphénoïde, soit par l'association de ces deux signes; nous en avons rapporté les caractères dans le Tableau 2.

La fréquence des asymétries par ordre de grandeur croissante (Tableau 3). Dans les conditions techniques que nous avons définies plus haut, les différences de diamètres sont inférieures à 3 mm dans 58 % des cas, elles ne dépassent pas 5 mm dans 95 % des cas et ne sont jamais supérieures à 8 mm.

Résultats des mensurations

Les caractères des asymétries dans les 50 cas dont les deux incidences avaient pu être mesurées. Nous avons confronté les résultats des mensurations pratiquées sur chaque incidence. Une symétrie transversale vérifiée sur les deux incidences

Tableau 3

Ordre de grandeur des asymétries mesurées sur les deux incidences

Siège	Total	Nombre de cas par différence de grandeur croissante (en mm)				
		1 à 3	3 à 6	6 à 9	9 à 16	16 et +
Diamètres transversaux:						
P	57	35	19	3	0	0
T	55	30	23	2	0	0
Th	56	32	19	5	0	0
Décalage des points S	55	34	20	1	0	0
Epaisseur de la voûte	32	30	2	0	0	0
Largeur du massif ethmoïdal	53	40	13	0	0	0
Sinus frontaux:						
profondeur	50	45	4	1	0	0
hauteur	64	36		23	3	2
largeur	60	36		21	2	1

n'existe dans aucun cas. 28 cas c'est-à-dire 56 % des sujets ont une asymétrie non systématisée: dans 17 cas, l'asymétrie est unilatérale sur chaque incidence mais les côtés ne concordent pas, dans les 11 autres cas, l'asymétrie est alterne sur une incidence et unilatérale sur l'autre (7 fois l'asymétrie est unilatérale sur l'incidence postéro-antérieure demi-axiale et 4 fois sur l'incidence axiale). 22 cas, c'est-à-dire 44 % des sujets, ont une asymétrie unilatérale de siège variable (Tableau 4). Dans 7 cas elle n'est démontrée que par une seule incidence tandis que dans les 15 autres elle se vérifie sur les deux incidences. Dans 16 % des cas elle intéresse tous les diamètres de telle manière que toute une moitié du crâne est plus petite que l'autre mais dans aucun de ces cas une voûte plus épaisse et un développement plus important des sinus ne coïncident du côté où les diamètres sont réduits. 50 % des cas ont une asymétrie des fosses temporales, la voûte n'est jamais plus mince du côté où la fosse temporale est plus grande (Tableau 5).

Pour rechercher une prédominance éventuelle de côté, nous avons classé les asymétries unilatérales en deux groupes suivant le côté réduit. La répartition se fait en nombre sensiblement égal à gauche et à droite dans l'incidence postéro-antérieure demi-axiale (Tableau 1) tandis que dans l'incidence axiale le côté gauche est réduit dans 69 % des cas (Tableau 2). Dans les 22 cas où l'examen du crâne était mesurable sur les deux incidences, c'est le côté gauche qui est réduit chez plus de 68 % des individus (Tableau 4); cependant, dans les 11 cas où l'asymétrie porte sur les fosses temporales, il n'y a plus aucun indice de dominance (Tableau 5) le côté droit étant plus petit chez 6 individus et le côté gauche chez les 5 autres.

Enfin, pour mettre en évidence un corrélation possible entre les asymétries

Tableau 4

Caractères des asymétries unilatérales observées chez les sujets dont les deux incidences étaient mesurables. Comparaison avec les variations du volume normal des ventricules latéraux.

Siège et côté de la réduction				Épaisseur de la voûte plus grande, égale ou moindre du côté réduit par rapport à l'autre			Développement des sinus plus marqué égal ou moindre du côté réduit par rapport à l'autre						Volume des ventricules latéraux		
							Sinus frontaux			Sinus éthmoïdaux			Égal	Asymétrique (Côté du ventricule + gros)	
No des cas	Siège	G	D	+	=	—	+	=	—	+	=	—		G	D
19	P, T, Th, S	+				+	+			+				+	
54	—		+		+				+	+			+		
77	—		+			+	+			+				+	
12	P, T, Th,	+				+	+					+	+		
13	—	+			+				+	+			+		
28	—		+		+				+	+				+	
83	—		+			+	+					+	+		
10	P, T, S	+			+				+	+			+		
21	—	+			+		+			+				+	
81	P, S	+		+			+					+	+		
3	P, Th, S	+		+			+					+		+	
5	—	+		+			+					+		+	
24		+				+			+			+	+		
27	T, Th, S		+			+			+			+	+		
29	T, S		+		+		+					+		+	
18	T, P	+		+			+				+			+	
26	—	+			+		+			+				+	
32	—	+		+			+					+	+		
66	P	+		+					+	+					+
86	T	+			+		+				+		+		
2	Th, S	+			+			+			+		+		
6	—		+		+		+					+		+	
		15	7	6	10	6	14	1	7	9	3	10	11	10	1

ventriculaires physiologiques (LINDGREN, RUGGIERO) et les asymétries cranien-nes normales, nous avons mis en parallèle les unes et les autres chez les 22 sujets où nos mensurations avaient démontré une asymétrie cranienne unilatérale contrôlée sur les deux incidences. Alors que les diamètres craniens sont réduits à gauche dans 69 % des cas et à droite dans 31 %; les ventricules latéraux, eux, sont symétriques dans 50 % des cas. Si le ventricule latéral gauche est

Tableau 5

Caractères des asymétries des fosses temporales dans les cas d'asymétries unilatérales observées chez les sujet dont les deux incidences étaient mesurables

No	Siège de l'asymétrie	Côté augmenté		Épaisseur de la voûte moindre, égal ou supérieure du côté plus grand pa rapport à l'autre côté		
		D	G	+	=	—
19	T, Th, S	+		+		
54	—		+		+	
77	—		+	+		
27	—		+	+		
12	T, TH	+		+		
13	—	+			+	
28	—		+		+	
83	—		+	+		
29	T, S		+		+	
10	—	+			+	
21	—	+			+	
Total: 11		5	6	5	6	0

plus gros que le droit dans 40 % des cas où le côté gauche du crâne est réduit, le ventricule droit n'est jamais plus gros que le gauche dans les cas où c'est le côté droit du crâne qui est réduit (Tableau 4).

Variations morphologiques

Rochers. Les principales anomalies décrites au niveau des rochers dans les asymétries craniennes pathologiques consistent essentiellement en pneumatisation du bord postéro-supérieur de l'os et décalage en hauteur ou obliquité plus importante de son grand axe. Ces anomalies sont décelables sur les clichés de face postéro-antérieure demi-axiale. Nous les avons recherchées dans nos 68 cas mesurables sur cette incidence. Dans aucun cas nous n'avons observé de pneumatisation unilatérale du bord postéro-supérieur mais dans 20 cas il y avait un léger décalage des axes en hauteur, 11 fois le droit était plus haut que le gauche et 9 fois le gauche plus haut que le droit. Parmi ces 20 cas, 4 avaient une réduction des diamètres transversaux de la fosse temporale d'un côté et tous les 4 du côté gauche; dans un cas le rocher droit était légèrement décalé vers le haut et le gauche dans les trois autres.

Mastoïdes. Dans 2 cas sur les 100, il y avait une asymétrie nette de développement des mastoïdes et dans un de ces cas le crâne avait ses diamètres réduits du côté opposé.

Thèque interne. Le relief de la thèque interne avait un aspect et une importance extrêmement variable d'un sujet à l'autre mais dans aucun cas nous n'avons observé d'asymétrie nette.

Petites ailes du sphénoïde. Dans tous les cas les petites ailes du sphénoïde avaient une morphologie normale et ne présentaient pas de décalage en hauteur.

Conclusion

1. Nous avons postulé que l'asymétrie pathologique traduisait par définition une modification du contenu cranien. Nous avons défini comme crâne normal, le crâne dont le contenu macroscopique était normal, c'est-à-dire où l'encéphalographie fractionnée n'avait montré ni déplacement ni déformation ni dilatation du système ventriculaire et des espaces sous arachnoïdiens.

2. Nous avons sélectionné 100 examens de crâne de sujets non épileptiques âgés de 15 à 50 ans répondant à cette définition. Tous ont été considérés comme normaux avec l'optique de routine habituelle.

3. Nous avons défini une méthode de mensuration.

4. 50 % des examens ne se prêtaient pas à des mensurations complètes.

5. Dans les 50 % restants, nos recherches démontrent que l'asymétrie cranienne est la règle. Elle a un caractère extrêmement variable. Chez un même sujet, elle peut intéresser le diamètre d'une région d'un côté et le diamètre d'une autre région de l'autre côté. Dans les conditions techniques que nous avons rapportées, les asymétries de diamètre ne dépassent pas 8 mm.

Parfois l'asymétrie n'intéresse qu'un seul côté du crâne, une moitié étant donc plus petite ou plus grosse que l'autre. Mais, quelle que soit l'importance de l'asymétrie, il ne s'y associe jamais de modifications morphologiques convergentes réalisant un tableau analogue à celui décrit soit dans l'hémi-atrophie cérébrale soit dans certains hématomes sous-duraux chroniques juvéniles.

Les termes d'hypoplasie et de ballonnement ne se prêtent donc pas à la description de l'asymétrie normale.

Les asymétries décrites par MacRae dans le tableau radiologique de l'épilepsie non tumorale peuvent rentrer dans le groupe des asymétries normales.

Dans l'asymétrie normale, il ne semble exister ni prédominance de côté ni corrélation de siège avec les asymétries ventriculaires physiologiques.

RÉSUMÉ

Par une méthode de mensuration qu'il a précisée, l'auteur a étudié les asymétries craniennes. Il a examiné les radiographies simples de 100 sujets âgés de plus de 15 ans, non épileptiques, dont l'encéphalographie fractionnée était normale. La moitié seulement de ces cas se prêtait à l'appréciation objective d'une asymétrie. Ce travail montre que l'asymétrie est la règle. L'auteur a recherché les signes quantitatifs et morphologiques qui permettent de la différencier de l'asymétrie pathologique qui traduit une modification macroscopique du contenu cranien.

SUMMARY

Cranial asymmetry was measured by a special method in conventional roentgenograms of 100 non-epileptics, over 15 years of age, with normal encephalograms. Complete measure-

ments were found to be possible only in about half the cases. Asymmetry within certain limit appear to be the rule. An attempt was made to find quantitative and morphologic changes bea ing a relationship to the different degrees of asymmetry so that the significance of the latter i terms of the macroscopic structure of the cranial contents might be indicated.

ZUSAMMENFASSUNG

Mit einer näher erläuterten Methode wurde an Übersichtsaufnahmen von 100 über 1 Jahre alten, nichtepileptischen Patienten, deren fraktionierte Enzephalographie normal wa Messungen der Asymmetrie des Schädels vorgenommen. Nur 50 % der Fälle eigneten sic für eine vollständige Messung, d. h. für die objektive Erkennung einer Asymmetrie. Di Arbeit zeigt als Ergebnis, dass die Asymmetrie die Regel ist. Der Autor versucht, quantita tive und morphologische Zeichen zu finden, die sie von einer pathologischen Asymmetrie un terscheiden lassen. Die Definition hierfür wird entsprechend der des normalen Schädels vo den makroskopischen Veränderungen des Schädelinhalts abgeleitet.

REFERENCES

Broca, P.: cité par Testut, L. et Latarjet, A.

Bull, J. W. D.: Radiological diagnosis of chronic subdural hematoma. Proc. roy. Soc. Med. 33 (1940), 203.

— Diagnosis of chronic subdural hematoma in infant and adolescent. Brit. J. Rad. 22 (1949), 68.

Childe, A. E.: Localised thinning and enlargement of the cranium with special reference to the middle fossa. Amer. J. Roentgenol. 70 (1953), 1.

Davidoff, L. M., Masson, C. B. and Dyke, C.: Cerebral hemiatrophy with homolateral hypertrophy of the skull and sinus. Surg. Gynec. Obstet. 57 (1933), 588.

Goalwin, J.: cité par Ledoux-Lebard, G. et Garcia-Calderon, J.

Hardman, J.: Asymmetry of skull in relation to subdural collection of fluid. Brit. J. Radiol. 12 (1939), 445.

Jackson, H.: Asymmetry and growth of the skull. Brit. J. Rad. 29 (1956), 521.

Jupe, M. H.: Reaction of bones of skull to intracranial lesions. Brit. J. Radiol. 11 (1938), 146.

Lebon, G.: cité par Talairach, J.

Ledoux-Lebard, G. et Garcia-Calderon, J.: Technique de radiodiagnostic, p. 358. Masson, Paris 1959.

Lefèvre, J., Guy, E. et Metzger, J.: Evolution des signes radiographiques des atrophies cérébrales unilatérales. Acta radiol. 40 (1952), 314.

Lindgren, E.: Eine enzephalographische Formvariante des Seitenventrikels. Acta radiol. 22 (1941), 722.

— Encephalography in cerebral atrophy. Acta radiol. 35 (1951), 277.

Lombardi, G.: Déformation crânienne par hématome chronique sous-dural et par hydrome. J. Radiol. Electrol. 35 (1954), 854.

MacRae, D. L.: Focal epilepsy: correlation of the pathological and radiological findings. Radiology 50 (1948), 439.

Olsson, O.: Instrument for ensuring symmetric pictures in roentgen examinations of the head. Acta radiol. 31 (1949), 240.

Porcher, P.: Précis de technique radiographique, p. 7. Gauthier-Villars, Paris 1948.

Ross, J.: Cerebral hemiatrophy with compensatory homolateral hypertrophy of the skull and sinus and diminution of cranial volume. Amer. J. Roentgenol. 45 (1941), 332.

RUGGIERO, G.: Encéphalographie fractionnée, p. 170. Masson, Paris 1957.
– – THIBAUT, A., HECAEN, H. et DELL, M. B.: Confrontation de données radiologiques, neurologiques et électroencéphalographiques dans 26 cas d'épilepsie non liés à un processus occupant de l'espace intracranien. R. X., radio-isotopes et E. E. G. dans l'épilepsie, p. 115. Masson, Paris 1960.
TALAIRACH, J.: Chirurgie stéréotaxique du thalamus. VIe. Congrès latino-Américain de Neurochirurgie. Montévidéo (1955), 865.
TESTUT, L. et LATARGET, A.: Traité d'anatomie humaine, Tome I, p. 285. Doin, Paris 1948.
THIBAUT, A.: Le tableau radiologique des collections liquidiennes encapsulées sous durales supratentorielles chroniques chez les jeunes. Neurochirurgie 4 (1958), 180.

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CALCIFICATION IN THE DISTAL RADIO-ULNAR JOINT

by

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LANG in his work on the distal radio-ulnar joint describes a case of an osseous loose body in the recessus sacciformis. Such a body may originate from a detachment of bony tissue from the radius or ulna, or from the cartilaginous surfaces of the bones or the articular disc. LANG also mentions the possibility of 'joint mice' being formed in osteochrondritis dissecans, cases of which have been described by THOMS and SCHÖNEICH although the bodies were not situated in the recessus sacciformis. LANG's patient had had a severe injury to the wrist and, in addition to arthritis of the carpal joints, there were marked osseous changes in the semilunar bone. He considered that the semilunar bone had been fractured and that a detached fragment had made its way up into the radio-ulnar joint through an existing or traumatic cleft in the disc. As this lesion is uncommon a report of a further case would appear to be justified.

A man, a potter aged 40, had for about two years been periodically troubled with pain in the left wrist, localized mostly to the dorsal aspect; it had become worse and prevented him working. No history of trauma. On examination, movements of the wrist caused pain but were not limited. No tenderness, swelling, or crepitation.

Roentgen examination of the left wrist revealed a dense, rather irregular body, about the size of a pea, at the proximal margin of the radio-ulnar articulation, lying slightly dorsally. No evidence of osteochrondritis dissecans, arthritis, or fracture. Right wrist normal. The patient was treated with radiotherapy (140 kV, 10 mA 3 mm Al, 100 r $\times$ 2 at 8-day intervals) following which the pain disappeared and he returned to work.

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Pneumoarthrography of left distal radio-ulnar joint. Calcification in recessus sacciformis.

The wrist is illustrated one month after the last treatment and following the injection of air. The calcified body lies in the recessus sacciformis and the joint capsule and distal fibres of the interosseous membrane are not affected. As the air was confined to the radio-ulnar articulation it is improbable that there was any communication between it and the recessus sacciformis.

Discussion

This patient's work as a potter involved frequent supination-pronation movements against resistance which are known to be a frequent cause of tendovaginitis crepitans. There is probably some causal association with peritendinitis calcarea in such cases. Tendovaginitis, peritendinitis or bursitis accompanied by calcification in the tissue involved may in addition to the shoulder region arise around the hip, knee, and ankle (SANDSTRÖM, MILLER) or more rarely in the fingers (JANSEN, OLDFIELD). KIERULF reported seven cases of peritendinitis calcarea in the region of the wrist in which the calcifications disappeared completely or almost completely after roentgen treatment.

The calcification in our case was presumably formed primarily in the wall of the recessus sacciformis and became detached from the synovial membrane. The good effect of irradiation is in conformity with the suggested aetiology.

SUMMARY

A case of calcification in the recessus sacciformis of the wrist shown by pneumoarthrography is described.

ZUSAMMENFASSUNG

Ein Fall mit einer Verkalkung im Recessus sacciformis des Handgelenkes, welche bei eine Pneumoarthrographie beobachtet worden war, wird beschrieben.

RÉSUMÉ

Description d'un cas de calcification du récessus sacciforme du poignet, mise en évidence par pneumo-arthrographie.

REFERENCES

JANSEN, K. F.: Calcareous peritendinitis. Acta radiol. 24 (1943), 285.

KIERULF, E.: Peritendinitis calcarea i håndledsregionen. (In Norwegian.) Nord. Med. 45 (1951), 975.

LANG, F.: Das distale Radio-Ulnargelenk. Unfallheilkunde 36 (1942), 3.

MILLER, C. F.: Occupational calcareous peritendinitis of the feet. Amer. J. Roentgenol. 61 (1949), 506.

OLDFIELD, M. C.: "Tennis thumb". Tendinitis with calcification in flexor policis longus. Lancet 1951: I, p. 1151.

SCHÖNEICH, R.: Osteochondritis dissecans am Ulna-Köpfchen. Fortschr. Röntgenstr. 76 (1952), 268.

THOMS, J.: Osteochondritis dissecans of the head of the ulna. Acta radiol. 34 (1950), 161.

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ATROPINE COMBINED WITH CARBACHOL FOR PROMOTION OF GASTRIC PERISTALSIS

by

B. G. DIJKEN and D. DE WIED

The fact that gastric peristalsis is sometimes poor has led to attempts at its stimulation during the roentgenologic examination. The first report on the use of drugs with which this can be effected was presented by RITVO & WEISS in 1927. The great advocate of pharmaco-roentgenology as a supplemental method of investigation, however, was PORCHER (1946, 1949, 1952, 1959).

Apart from pharmacologic stimuli to promote gastric motoricity, electric, psychogenic, mechanical and thermal means have also been employed for this purpose. By electric stimulation of the vagus nerve (by means of a catheter in the oesophagus), a very marked increase in motoricity can be effected (STAHNKE & SEYERLEIN 1925). This method must be regarded as hazardous, however, as it may result in disturbances in the cardiac rhythm. Personal observations have shown that faradic stimulation of the associated skin segments as well as psychogenic and thermal stimuli produced no noteworthy effect. We often observed a definite increase in motoricity following palpation of the gastric region, after instructing the patient to take deep breaths, or after placing him in the prone position. Before resorting to the use of drugs, it should be borne in mind that these should not produce any untoward or toxic symptoms and should be suitable for ambulatory patients. The number of drugs or combined drugs mentioned in connection with this stimulation of peristalsis is relatively large although not all of them meet the necessary requirements.

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RASMUSSEN (1950) was the first to use subcutaneous injections of atropine combined with prostigmine to increase peristaltic movements during the roentgenologic examination of the stomach. ROLLANDI & SCARPONI (1951) and ROLLANDI (1953) reported on the intravenous administration of these drugs in combination.

Personal observations

In view of reports in the literature on the use of atropine combined with prostigmine, we decided to study the effect of these drugs. Since atropine is an antidote to prostigmine there is no pharmacologic objection to their combined use. Intravenous administration might produce undesirable effects. The effect was studied in 20 patients by injecting 0.5 mg atropine and 0.5 mg prostigmine subcutaneously from one syringe. It was found that the desired motor effect remained absent and appeared to be inhibited by the preceding filling of the stomach and the examination of the patient in the upright position. (See Table 1.)

As prostigmine is the more active of the two drugs, another parasympathomimetic carbachol, which exerts its influence more directly, was selected. This is a cholinester with a marked cholinergic action (KREITMAR 1932). Its most important sites of action in man are the musculature of the digestive tract, bladder and heart. STEIN, MEIJER & STEIGMAN (1948) and HENNING, KINSELMEIJER & DEMLING (1952) registered the motor manifestations by introducing a balloon into the stomach. It was found that carbachol caused a marked increase in motoricity even in patients who had undergone complete vagotomy. It was also observed that carbachol, as compared with prostigmine, caused considerably more marked increase in peristalsis in normal test subjects.

GOODMAN & GILLMAN (1955) reported that atropine should theoretically completely block the cholinergic innervation of the gastro-intestinal tract. They contended, however, that in practice this substance is known to counteract the effects of parasympathomimetics such as carbachol but to suppress only incompletely the effects of vagal impulses on the gastro-intestinal tract.

Examination of the motor effect in 65 patients showed that the subcutaneous injection of 0.5 mg atropine and 0.4 mg carbachol always caused a marked increase in peristalsis 8 to 15 minutes after their injection. The filling of the stomach and the examination erect were found not to impair the effect. The only side-effect observed was the urge to urinate in 4 cases; the examination had therefore to be briefly interrupted in 2 cases. Doses of 0.25 and 0.5 mg proved to be less satisfactory (Table 1).

It is advisable to reduce the dose of carbachol to 0.25 mg in cases of asthma as this substance may provoke an attack of dyspnoea (STARR 1937). In view of this fact, ten asthmatics who showed hypersensitivity to acetylcholine were submitted to a limited lung function test which revealed that a subcutaneous injection of 0.25 mg carbachol and 0.5 mg atropine was not contraindicated.

Table 1

The effect of various drugs on motoricity in human subjects. Patients with ectasia of the stomach from juxtapyloric stenosis not included.

Subcutaneous injection	x 0.5 mg atrop.-sulf. + 0.5 mg prostigmine, before drinking the barium		xx 0.5 mg atrop.-sulf. + 0.5 mg prostigmine, after drinking the barium		xx 0.5 mg atrop.-sulf. + 0.25 mg carbachol after drinking the barium		xxx 0.5 mg atrop.-sulf. + 0.4 mg carbachol after drinking the barium		xxxx 0.5 mg atrop.-sulf. + 0.5 mg carbachol after drinking the barium	
Number of observations	8		12		24		65		10	
	Prone	Standing	Prone	Standing	Prone	Standing	Prone	Standing	Prone	Standing
Increase in motoricity..	8	8	11	8	24	21	65	65	10	10
No change in motoricity	0	0	1	4	0	3	0	0	0	0

x Insufficient peristalsis during one observation
xx » » » two different observations
xxx » » » » » » in 40 of 65 patients
xxxx » » » » » » » 6 » 10 »

The pharmacologic effect of the atropine carbachol combination. It has been stated that a cholinergic effect on the gastric musculature occurs in man following the combined administration of a parasympathomimetic (carbachol) and a parasympatholytic drug (atropine). This observation is rather strange because atropine is the antidote par excellence against violent motor changes in the gastro-intestinal canal which may occur after carbachol treatment (GOODMAN & GILLMAN 1955). An attempt will be made to explain this apparent paradox by reports of investigations in rats and man, and in vitro investigations on the human stomach.

Investigations in rats. The rat is the most suitable animal for experimental investigation of the gastro-intestinal tract (GODLEWSKI 1951). The size of the animals and their cost do not prohibit large scale investigations. We used white female rats with an average bodyweight of 200 g, 3 ml barium meal being introduced into the stomach by means of a Nelaton catheter No. 10, the test animals then being placed in plastic tubes of 5 cm diameter. Five of such tubes were fixed in a wooden rack. Under these conditions it is possible by means of fluoroscopy and roentgenography to make continuous observations on the peristaltic phenomena and the emptying of the stomach. As the test animals are sufficiently firmly fixed this arrangement renders anaesthesia unnecessary.

Table 2

Roentgenologic observation in rats

Subcutaneous injection	0.4 ml 0.9 % saline	6.6 γ atrop. sulf.	6.6 γ carba-chol	6.6 γ atrop. sulf. + 6.6 γ carba-chol	2 × 6.6 γ atrop. sulf. and after 20 min 6.6 γ carbachol	50 γ atrop. sulf.	50 γ atrop. sulf. + 6.6 γ carba-chol	50 γ atrop. sulf. and after 30 min 6.6 γ carbachol
Increase in motoricity	0	3[1]	10	10	9	0	10[4]	0
No change in motoricity ..	10	12	0	0	0	0	0	10
Decrease in motoricity	0	9[2]	0	0	0	10[3]	0	0

[1] moderate, [2] 25 min after injection, [3] 5 min after injection, [4] moderate, short lasting effect.

We found that a subcutaneous injection of physiologic saline produced day-to-day variations in the motor manifestations of the stomach in the same animal. We also noted a daily difference in the emptying rate. These observations were confirmed during subsequent investigations in which the subcutaneous injection was always preceded by a 30 min period of observation. No effect whatever was seen after a small dose of atropine. The same quantity of carbachol, however, caused a marked increase in the motor effect. The motor intensity seen after the combined administration of equal doses of both drugs did not differ from that observed after the administration of carbachol alone. Nor was a difference noted when this quantity of atropine was given in advance. Increased doses of atropine, however, caused a decrease in motoricity and after the administration of a large dose of atropine combined with a much smaller dose of carbachol there was, surprisingly, a moderate increase in peristalsis during a brief initial period, which was followed by atonia. No increase in the motor effect occurred, however, when a large dose of atropine was given first and followed by carbachol after a certain interval. (See Table 2.)

These observations in rats warrant the conclusion that carbachol causes an increase in motoricity and that this is not suppressed by an identical quantity of atropine. Atropine in a sufficiently high dosage inhibits the effect of carbachol, but only after a certain interval.

Roentgenologic investigations of the human stomach. In view of the above observations in rats, further investigations in human subjects were performed. No decrease in the motor effect in the stomach after the subcutaneous injection of 0.5 mg atropine was seen until after 30 min. In agreement with the observations made in rats, we found no difference between the effect of a subcutaneous injection of 0.5 mg atropine combined with 0.25 mg carbachol and that of 0.25 mg carbachol alone, during the first 15 minutes. However, when 0.5 mg atropine was first given, followed after 20 min by 0.5 mg carbachol, the motor

Table 3

Study in 10 human subjects

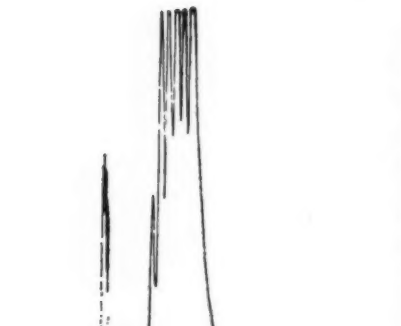
Subcutaneous injection	0.5 mg carbachol	0.5 mg atrop. sulf. + 0.5 mg carbachol
Fall in blood pressure	Syst. 5 to 10 mm Hg Diast. 10 to 15 mm Hg	Syst. 0 mm Hg Diast. 0 to 5 mm Hg
Sweat secretion	Marked effect	No effect
Heat sensations	Marked effect	No effect
Salivation	Moderate effect	No effect

effect of the latter drug proved to be completely blocked. These observations show that also in man some time must elapse before atropine inhibits the motor effect of carbachol on the stomach.

Blocking effect of atropine on the parasympathomimetic activity of carbachol. It is a remarkable fact that after the subcutaneous injection of atropine-carbachol an increase in gastric peristalsis occurs, whereas none of the other phenomena associated with the administration of carbachol is seen. In view of this fact we studied the general phenomena produced by this combination as compared with those produced by carbachol alone in the same test subject. An examination of 10 subjects showed that the decrease in blood pressure, hyperhidrosis, heat sensations and salivary activity observed after the administration of 0.5 mg carbachol do not occur (or to a much less marked degree) after this dose combined with 0.5 mg atropine. The urge to micturate, the urge to defaecate, and borborygmi were reported in the same frequency. (See Table 3.)

In vitro investigation of the human stomach. This study was made with fresh surgical specimens obtained at partial gastrectomies for benign conditions of the stomach or the duodenum. The resected specimen was washed off with 'perfusion fluid', in which it was kept at a temperature of 4° C. The investigation in the gastro-intestinal tray took place 3 to 5 hours later. The stomach was opened along the greater curvature. A strip of the gastric wall, 2 to 3 mm wide and 3 cm in length, was cut off 3 to 4 cm in front of the pyloric region, perpendicular to the longitudinal axis of the stomach. The mucosa was dissected off, after which the strip of muscle was suspended in the gastro-intestinal tray. (Composition of fluid: 16 g NaCl, 0.4 g KCl, 0.4 g $CaCl_2$, 0.3 g $MgCl_2$ 6 H_2O, 2 g $NaHCO_3$, 0.1 g NaH_2PO_4 2 H_2O, 2 g glucose in 2 l distilled water; temperature 37° C; capacity of bath 5 ml.)

A contraction was invariably seen after the addition of carbachol. This, however, was immediately controlled and blocked by the addition of atropine as illustrated in the figure. These observations therefore contradict the observations made in vivo.



Effect of carbachol (50 γ per 5 ml) before and after the addition of atropine sulfate (50 γ per 5 ml). In vitro investigation of the human stomach. Immediate spasmolytic effect of atropine during carbachol contraction.

It has been shown in the above that when carbachol and atropine are simultaneously administered in equal doses, the latter drug does not immediately suppress gastric peristalsis, but immediately controls other signs produced by carbachol, namely decreased blood pressure, sweat secretion, heat sensations and salivation. The parasympathomimetic effect of carbachol on the peripheral blood vessels and the suderiferous and salivary glands is therefore more rapidly suppressed by atropine than are the motor phenomena of the visceral system. This is in accordance with the in vivo effect produced by atropine alone. The in vitro findings, which are not in agreement with this, may be explained by the presumption that under these conditions there is a difference in the susceptibility of the end organs to the inhibitory effect of atropine.

Discussion

Morphine is the agent most frequently used to promote the motoricity of the human stomach. PORCHER et coll. reported some 15 000 observations in which a subcutaneous injection of 10 mg was employed (PORCHER, STÖSZEL & BAINQUET 1959). Some 80 % of the cases showed increased motoricity for twenty minutes after the injection, this being followed by a phase of gastric atonia. Similar observations were made by SAUVEGRAIN (1946), RASMUSSEN (1949), ALBOT & CORTEVILLE (1952), STÖSZEL (1953), GÎMES (1955), and PFEIFFER (1956). We have refrained from using this drug because in these doses it can produce side-effects such as collapse, nausea and vomiting (PORCHER 1946, PORCHER et coll. 1949, BLONDET et coll. 1949, RASMUSSEN 1950, ALBOT & CORTEVILLE 1952). Taking into consideration that the motor effect remains absent in 20 % of cases, that the effect occurs only in the prone position and is not always observed when the stomach is filled with barium, it may be stated that this agent does not appear to be the one of choice for promoting gastric peristaltic movements.

ALBOT, RENAUX & GIRARD (1946) and ALBOT & CORTEVILLE (1952) administered 10 to 20 U. insulin intravenously. PORCHER (1952) and ADLER et coll. (1955) contended however that only a poor and not convincing increase

i motoricity can thus be produced. Since insulin at the dosage indicated pro- ces disagreeable side-effects and apparently does not always cause the desired r sult this agent must also be considered unsuitable.

HENNING, KINZELMEIJER & DEMLING (1952) administered the posterior p tuitary extract Piton (Organon, Oss, Holland) and registered the increase i. gastric peristalsis by the balloon method. Gastroroentgenologic examina- t ons by VELDE (1933) revealed first a decrease and subsequently an increase in r otoricity, which suggests that this extract is not entirely satisfactory. The h ypersecretion and increased blood pressure and constriction of the coronary v essels caused by this agent must moreover contraindicate its use.

An increase in tone and peristalsis is seen after the administration of acetyl- c oline in sufficiently large doses. The dosage required, however, is above the p ermissible limit, and the effect is not constant. This is probably due to its r apid breakdown, the reason why it is replaced for clinical purposes by more s able substances such as carbachol and urocholine.

RITVO & WEISS (1927) & RITVO (1936) administered physostigmine orally (2.6 mg) or subcutaneously (1.3 mg) and found that the desired motor effect occurred in about 85 % of cases. Since the maximal permissible dosage must be exceeded, and the effect does not always occur, this substance does not appear an acceptable one for our purpose. RASMUSSEN (1950) observed an increase in motoricity in 22 of 34 patients given a subcutaneous injection of 0.5 mg prostig- mine (neostigmine). Corroborating reports were presented by VEACH, LAUER & JAMES (1938) who used an intravenous injection of 0.5 to 2.0 mg.

There is no agreement as to the effect of atropine on the motoricity of the stomach. Roentgenologic observations seem to indicate that, in the case of atonia, a moderate increase in gastric peristalsis occurs during the first 10 to 15 minutes followed by marked inhibition after about 30 minutes (VELDE 1933, SAUVEGRAIN 1946, DERIU 1949, PORCHER 1952). PORCHER pointed out that the motor effect is poor, so that the more effective substance morphine should be preferred. Our observations in 10 subjects showed that a subcutaneous in- jection of 0.5 mg atropine caused only a slight increase in motoricity in a few cases.

With regard to the employment of a subcutaneous injection of atropine- carbachol, it can be stated that it invariably produces an increase in gastric peristalsis even after the stomach has been filled with barium and the patient is examined erect. The absence of certain symptoms which occur after the ad- ministration of carbachol alone is fortunate and is in agreement with other investigations showing that the sensitivity of the postganglionic parasympathetic nerve fibres to atropine varies widely from organ to organ. In dogs, for example, the effect on the heart of electric stimulation of the vagus is completely controlled by the intravenous injection of 0.1 mg/kg bodyweight atropine; 0.5 to 1.5 mg/kg is required to inhibit the salivation caused by electric stimulation of the chorda tympani. Much larger doses are necessary to prevent contraction

of the urinary bladder as a result of stimulation of the sacral parasympathetic nerves (HENDERSON & ROEPKE 1937).

The fact that the urge to urinate occasionally necessitates a brief interruption of the examination is no contraindication to the use of this combination of drugs.

SUMMARY

The subcutaneous injection of atropine combined with carbachol was found invariably to produce a marked increase in gastric peristalsis. In vivo investigations in rats and humans subjects showed that some time elapses before atropine inhibits the cholinergic effect of carbachol on the gastric musculature, although it rapidly controls any side-effects produced by the latter drug.

ZUSAMMENFASSUNG

Die subkutane Injektion von Atrophin in Kombination mit Karbachol erzeugte ständig deutlichen Anstieg der Magenperistaltik. Untersuchungen an lebenden Ratten und Beobachtungen beim Menschen zeigten, dass es eine gewisse Zeit dauert bevor das Atrophin den cholinergischen Effekt des Karbachols auf die Magenmuskulatur inhibiert, obwohl es alle Nebenwirkungen, welche durch die letztere Droge erzeugt werden, schnell unter Kontrolle bekommt.

RÉSUMÉ

Les auteurs ont constaté que l'injection sous-cutanée d'atropine associée au carbachol augmente toujours de façon marquée le péristaltisme gastrique. Les recherches in vivo sur des rats et des sujets humains on montré qu'un certain temps s'écoule avant que l'atropine n'inhibe l'effet cholinergique du carbachol sur la musculature gastrique, bien qu'elle empêche rapidement les effets secondaires dûs à ce produit.

REFERENCES

ADLER, D. C., JACOBSON, G., HEITMANN, K. A. and WATSON, D. D.: Insulin-induced hypermotility in the roentgen examination of the stomach and duodenum. Radiology 65 (1955), 530.

ALBOT, G. en CORTEVILLE, M.: Pharmacoroentgenografie van maag en duodenum. Belg. T. Geneesk. 8 (1952), 673.

— RENAUX, J. et GIRARD, E.: Un nouvel agent pharmacoradiographique; l'insuline intraveineuse. Arch. Mal. Appar. dig. 35 (1946), 118.

BLONDET, P., BUFFARD, P., BRET, P. et ROCHE, P.: La morphine par voie buccale en radiologie digestive. J. Radiol. Electrol. 46 (1949), 30.

DERIU, G.: Prova farmaco-dinamica coll' atropina nella radiodiagnostica gastro-duodenale. Radiol. med. 35 (1949), 939.

DIJKEN, B. G.: De waarde van peristaltiek bevorderende farmaca bij het röntgenologische maagonderzoek. Thesis, Groningen 1959.

GÎMES, B.: Die Bedeutung der Pharmacoradiologie in der Differentialdiagnose des praepylorischen Ulcus. Fortschr. Röntgenstr. 83 (1955), 771.

GODLEWSKI, M.: A la recherche d'un animal réactif idéal pour les épreuves pharmaco-dynamiques en radiologie digestive. Arch. Mal. Appar. dig. 40 (1951), 234.

— Action de la prostigmine sur le tube digestif radiologique de quelques animaux. Arch. Mal. Appar. dig. 40 (1951), 796.

GOODMAN, L. S. and GILLMAN, A.: The pharmacological basis of therapeutics. The Macmillan Company, New York 1955.

HENDERSON, V. E. and ROEPKE, M. H.: Drugs affecting parasympathetic nerves. Physiol. Rev. 17 (1937), 373.

HENNING, N., KINZELMEIER, H. und DEMLING, L.: Fortlaufende Registrierung verschiedener Magenfunktionen beim Menschen unter dem Einfluss von sekretions- und motilitätsfördernden Substanzen. Z. ges. exp. Med. 118 (1952), 177.

HEITMAR, H.: Eine neue Klasse Cholinester. Arch. Path. Pharmak. 164 (1932), 346.

HEIFFER, J.: Pharmacoradiografie des Magens. Fortschr. Röntgenstr. 84 (1956), 421.

HORCHER, P.: L'hyperkinésie gastrique provoquée. Technique nouvelle de l'exploration complémentaire de l'estomac et du bulbe duodénal. J. Radiol. Electrol. 27 (1946), 393.

— — Les modificateurs de comportement en radiodiagnostic digestif. France méd. Gastroentérol. 1 (1952), 13.

— — STÖSZEL, H. U. und BAINQUET, P.: Die klinische Untersuchung des Magens und des Zwölffingerdarmes. Thieme, Stuttgart 1959.

— — BOURDON, R., BAUDAGHIAN, B. et SAUVEGRAIN, J.: Bilan de la morphine après 6 000 examens. Arch. Mal. Appar. dig. 38 (1949), 942.

HASMUSSEN, TH.: Pharmacoradiografi af ventriklen ved hjælp af morfin og ipecacuanha (Danish). Nord. Med. 41 (1949), 980.

— — Pharmacoradiografi af ventriklen (Danish). Nord. Med. 44 (1950), 1563.

RITVO, M.: Drugs as an aid in roentgen examination of the gastro-intestinal tract. The use of mecholyl, physostigmine and benzedrine in overcoming atonicity, sluggishness of peristalsis and spasm. Amer. J. Roentgenol. 36 (1936), 868.

— — and WEISS, S.: Physostigmine as an aid in gastro-intestinal roentgen-ray diagnosis. Amer. J. Roentgenol. 18 (1927), 301.

ROLLANDI, A.: Ancora sull'impiego della prostigmina ad atropina associate nello studio farmacoradiologico dello stomaco e del duodeno. Riv. ital. Radiol. clin. 3 (1953), 2.

— — e SCARPONI, F.: L'associazione prostigmina-atropina nell'esame radiologico dello stomaco e duodeno con particolare riguardo alla stenosi pilorica. Minerva med. (Torino) 2 (1951), 73.

SAUVEGRAIN, J.: Utilisation systématique de modificateurs de comportement en radiologie gastro-duodénale. Thésis, Paris 1946.

STAHNKE, E. und SEIJERLEIN: Elektrische Vagusreizung beim Menschen. Münch. med. W.-schr. 73 (1925), 334.

STARR, I.: Carbaminoylcholine (doryl or lentin). Its action on normal persons, in peripheral vascular disease and in certain other clinical conditions. Amer. J. med. Sci. 193 (1937), 393.

STEIN, I. F. and MEYER, K. A.: The use of insulin in testing for completeness of vagotomy. Surg. Gynec. Obstet. 86 (1948), 473.

— — and STEIGMAN, F.: Changes in gastric motility and the effect on motility of following complete vagotomy. Surg. Gynec. Obstet. 87 (1948), 465.

STÖSZEL, H. U.: Die klinische Bedeutung der Pharmacoradiografie ins besondere des Morphins bei Erkrankungen des Magens und des Duodenums. Schweiz. med. Wschr. 83 (1953), 657.

VEACH, H. O., LAUER, B. R. and JAMES, A. G.: Effects of prostigmine and atropine in the human stomach. J. Pharmacol. 62 (1938), 422.

VELDE, G.: Die Magenschleimhaut bei Achylia Gastrica und perniciöse Anaemie. Ihr Verhalten auf vegetativen Reizen. Ergebn. med. Strahlenforsch. 6 (1933), 347.

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GENERAL THEORY OF NARROW BEAM ROTATION TOMOGRAPHY

by

PEKKA SOILA

Narrow beam rotation tomography, panoramic tomography, or pantomography, has been developed to a practical and useful roentgenographic procedure by PAATERO (1949, 1954). This author has presented mathematical formulae of several aspects of pantomography (1954, 1956), and further mathematical data have been published by DUHAMEL (1955), HUDSON, KUMPULA & DICKSON (1957), and VUORINEN (1959). These investigations have dealt with important aspects of pantomography, e. g. the positioning of the film, the thickness of the depicted layer, and the characteristics of an extremely narrow beam of radiation.

Certain theoretical facts as well as the availability of equipment similar to pantomographs have necessitated a general investigation of the theory of this type of tomography. It is well known that the transversal tomograph of VALLEBONA (1952) can be used for longitudinal tomography. In the standard equipment the roentgen beam is directed horizontally, while the patient and the film are made to rotate vertically. Such a method is in routine use wherever equipment based on this principle has been installed. A full beam of radiation is employed and no investigations appear to have been published on

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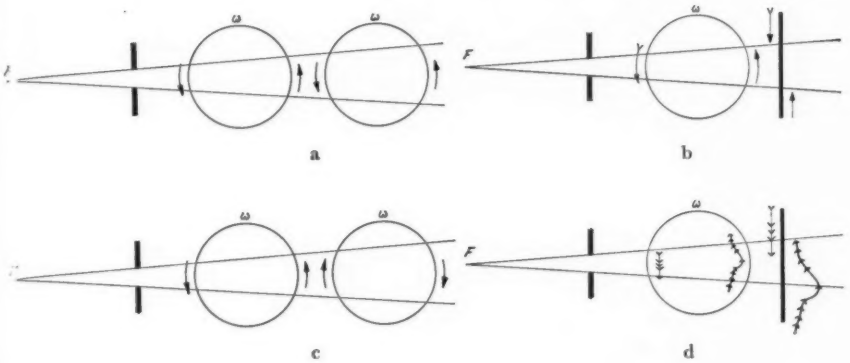

Fig. 1. Various combinations in the application of narrow beam rotation tomography. a) Vallebona type, patient and film disk rotating in same direction: beam is narrow but film curved. b) and c) Variations of pantomography. d) Two further developments of the technique.

the use of a narrow beam in combination with this adaptation. Attempts to rotate the disks in opposite directions do not seem to have been recorded. A general and relatively simple mathematical consideration of the theory of the various combinations of rotation tomography, with special regard to the use of a narrow beam, would therefore appear to be of interest and value.

The possible combinations in the application of the technique are shown in Fig. 1. In (a) the patient and film disks rotate in the same direction but the beam is limited and the film may be straight or curved. The part nearest to the focus or the part farthest away will be depicted according to the position of the film. The geometrical conditions are clearly more favourable in the latter case, and in practice the corresponding variation has been most commonly used.

The principle of pantomography with the disks rotating in opposite directions is exemplified in Fig. 1c. Obviously improved geometrical conditions are obtained by placing the film to the focus side of the film disk. This was PAATERO's solution of the problem in his original communication (1949). Other uses of this method may however be of importance. An enlarged image may, for example, be obtained by placing the film on the far side of the film disk and calculating the layer to be depicted from the focus side of the object. The conditions obtained in Fig. 1a obviously represent a middle road solution between the two extremes provided by pantomography. Certain problems connected with optimal blurring may be approached by a consideration of the positioning of the patient in relation to the rotation axes.

Another variation of pantomography is shown in Fig. 1b, originally suggested by PAATERO (1955) especially for stereo-pantomography, and later put into practical use by HUDSON et coll. as well as by the present author. This method is

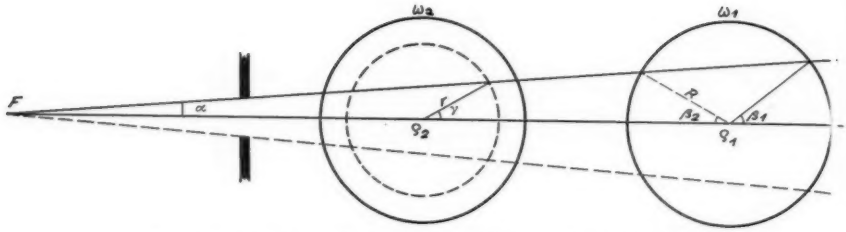

Fig. 2. Combination of the variations presented in fig. 1 (a) and (c).

useful as no curved films are needed but it also makes possible the use of the focus side of the patient disk, as suggested above. These possibilities are illustrated in the drawing by similar arrows. The small error caused by flattening the film will be dealt with below.

Two further developments of the technique are presented in Fig. 1d. Pantomography has so far been used practically exclusively in examinations of the jaws. The longitudinal variation of the technique of VALLEBONA has been performed with a full beam of roentgen rays, a flat film traversing the beam during a continuous change of angle between it and the central ray. PAATERO (1956) also published an investigation of pantomography of flat layers, in which a rotating film disk and a varying central ray-film angle were employed. The use of the narrow beam rotating methods in other fields of medical roentgenography should be planned with due consideration to the possibility of depicting other than cylindrical or similar simple curved layers. In variation (b) as well as in the modification (d) the central ray and the film are perpendicular to each other during the whole exposure. This arrangement also makes possible the depiction of a great number of varying layers. In (d) the focus side layer of the object in effect reproduces a flat layer on a flat film, with preservation of the perpendicular central ray-film angle. The film side layer of the object illustrates the possibility of depicting an arbitrary layer in a film moving at a changing and corresponding speed. Only layers with a curve approaching the direction of the central ray present difficulties in this modification of the technique while a great number of mathematical or otherwise prearranged layers may obviously be depicted.

The variations in Fig. 1, a and c, are combined in Fig. 2, from which the following equations for the angles β and γ may be obtained:

$$\beta = \overline{\text{arc sin}} \left(\frac{\varrho_1}{R} \sin \alpha\right) \pm \alpha$$

$$\gamma = \overline{\text{arc sin}} \left(\frac{\varrho_2}{r} \sin \alpha\right) \pm \alpha$$

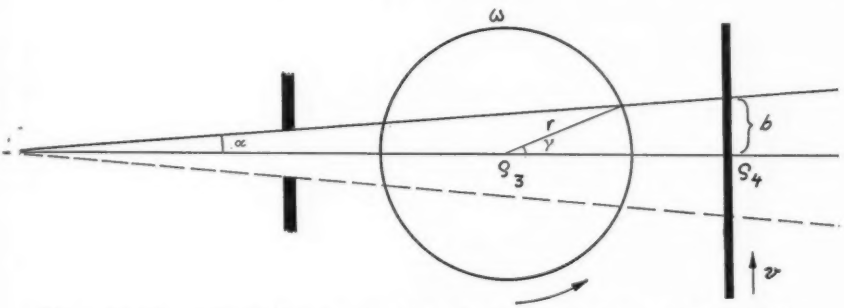

Fig. 3. Variation of the solution presented in fig. 1b, based upon the use of a flat cassette.

The + and — signs obviously provide four combinations of rotational movements in all, which correspond to the four alternatives presented in Fig. 1, a and c. Provided the object disk and the film disk rotate at angular velocities ω_2 and ω_1, the times t_2 and t_1 for a given point of the object and for a given point in the film to traverse through the roentgen beam are as follows:

$$t_1 = \frac{\beta\,(r)}{\omega_1}, \text{ function of } r; \; t_2 = \frac{\gamma}{\omega_2}$$

The time difference t_1—t_2 between the traversing time of an object point and a film point is as follows:

$$\left| t_1 - t_2 \right| = \left| \frac{\beta}{\omega_1} - \frac{\gamma}{\omega_2} \right|$$

This time difference is caused by divergence of the roentgen beam; the blurring and the dimensions of the image layer may be calculated with the help of the time difference, as follows:

$$\Delta s = (t_1 - t_2)\, R\omega_1, \; \Delta s \leqq d$$

In the equations the letter d indicates the resolution of the film, meaning the minimum distance between two points in the film for these to be resolved.

The distance R, that is the position of the film for depicting a desired layer of the object, may be obtained as follows:

$$\frac{\sin\beta}{\sin\gamma} = \frac{\dfrac{\varrho_1}{R} \pm \cos\beta}{\dfrac{\varrho_2}{r} + \cos\gamma}, \text{ or}$$

$$R = \frac{\varrho_1}{\mp\cos\beta + \dfrac{\sin\beta}{\sin\gamma}\left(\dfrac{\varrho_2}{r} + \cos\gamma\right)}$$

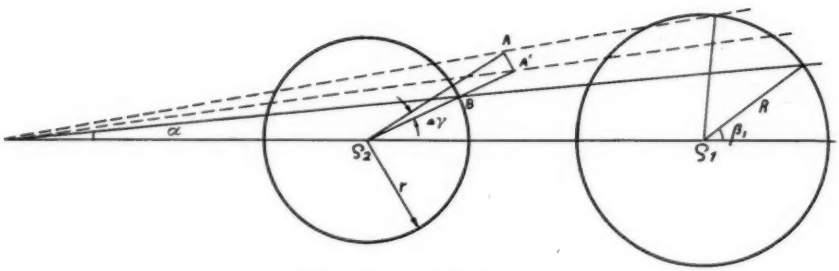

Fig. 4. Geometrical relations.

A variation of the alternative in Fig. 1b, based upon the use of a flat cassette is presented in Fig. 3. Its advantage, apart from the convenience of its use, is the simplification in the positioning of the object in relation to the focus and the film. It is possible to choose the position of the object to suit the requirements of the examination, while the relevant calculations and the handling of the film become relatively simple.

The following equation may be derived from Fig. 3.

$$b = \varrho_3 \operatorname{tg} \alpha = \frac{\varrho_4 \sin \gamma}{\varrho_3 - r \sin \gamma} r$$

$$t = \frac{b}{v}, \text{ or generally } t = \frac{b}{\bar{v}}$$

$\bar{v}$ is the mean velocity, $\bar{v} = \frac{1}{t_0} \int^t v dt$

The image layer $\Delta r = r' - r''$ may be calculated with the help of the time difference t_1—t_2 from the condition $\Delta b \leq d$, where

$$\Delta b = b' - b'' = \frac{\varrho_4 \sin \gamma}{\varrho_3 - r' \cos \gamma} r' - \frac{\varrho_4 \sin \gamma}{\varrho_3 - r'' \cos \gamma} r''$$

As stated above the layer of the object to be depicted as well as the corresponding speed of the film may follow the course of several geometrical surfaces or other prearranged paths.

The depicting capacity of the method is dependent upon the directions of the central ray and the layers to be depicted being parallel or nearly parallel to each other. The following approach may be considered for this case (for the geometrical relations, see Fig. 4):

The points A and A', are separated by the radial difference Δr. This difference has an upper limit at which these two points will be clearly represented in the

fil n. This condition may be expressed in a mathematical formula with the help of differential calculus:

$$|\Delta r| \geqq \frac{\frac{\varrho_2}{r}\cos\beta_1 + \cos\gamma\cos\beta_1 + \sin\gamma\sin\beta_1}{\sin\beta_1} \cdot \frac{r^2}{\varrho_2}\frac{d}{R}$$

w ere d indicates the resolution in the film.

The points A' and B must be a minimum distance apart in order to be cl arly represented. This gives the condition

$$\frac{\cos(\gamma-\alpha)}{\cos(\gamma+\alpha)} \frac{\frac{\varrho_1}{R} + \cos\beta_1}{\frac{\varrho_2}{r} + \cos\gamma} r\Delta\gamma \geqq d$$

Combining these two conditions we obtain the minimum value for the angle $\varnothing$ between the line AB and the radius $\bar{r}$,

$$\varnothing \geqq \operatorname{arc\,tg}\left\{\frac{\sin\gamma}{\frac{\varrho_2}{r}\cos\beta_1 + \cos(\gamma+\beta_1)} \cdot \frac{\cos(\gamma+\alpha)}{\cos(\gamma-\alpha)} \frac{\varrho_2 R}{r^2}\right\}$$

The equations for β_2 may be written with the substitution

$$\beta_1 = \pi - \beta_2$$

It is evident that the angle of divergence plays an important role in every practical application of rotation tomography. Experiments are now in progress to verify the validity of the theoretical considerations and to investigate the effect of the angle of divergence in the different combinations.

This investigation was carried out during the author's tenure of a James Picker Foundation Research Fellowship at the Central Hospital, Turku University, Finland, and Karolinska Sjukhuset, Stockholm, Sweden.

SUMMARY

A theoretical generalization of the various types of rotation tomography in practical use is presented. The developed formulae cover certain problems of optimal conditions for reproduction of the part of the object required.

ZUSAMMENFASSUNG

Eine theoretische Verallgemeinerung verschiedener, praktisch angewendeter Methoden d r Rotationstomographie wird vorgelegt. Die entwickelten Formeln ermöglichen die Lösung e iiger Probleme der Rotationstomographie, welche die optimalen Abbildungsverhältnisse b handeln.

RÉSUMÉ

L'auteur présente une théorie générale des divers types de tomographie rotatoire utilis s en pratique. Les formules qu'il propose permettent de résoudre certains problèmes concerna t les conditions optimales pour reproduire la partie de l'objet à examiner.

REFERENCES

DUHAMEL, J.: Les procédés de radiographie en coupe non rigoreux. Sci. Indust. phot. 2 5 (1954), 129.

— Une forme nouvelle de phototomographie. La photopantomographie de Y. V. Paater . Sci. Indust. phot. 25 (1954), 353.

HUDSON, D. C., KUMPULA, J. W. and DICKSON, G.: The panoramic X-ray dental machine. U. S. Armed Forces Med. J. 8 (1957), 46.

PAATERO, Y. V.: A new tomographical method for radiographing curved outer surfaces. Acta radiol. 32 (1949), 177.

— Pantomography in theory and use. Acta radiol. 41 (1954), 321.

— Theoretico-experimental study on the origin of the stereoscopic effect in pantomography. Suom. Hammaslääk. Toim. 50 (1954), 193.

— On the pantomography of straight layers. Suom. Hammaslääk. Toim. 52 (1956), 84.

— The principles of the construction and function of the stereopantomograph. Acta radiol. 43 (1955), 113.

VALLEBONA, A.: Trattato di stratigrafia. Vallardi Ed., Milano 1952.

VUORINEN, P.: The roentgenographic slit methods. Acta radiol. (1959) Suppl. No. 177.

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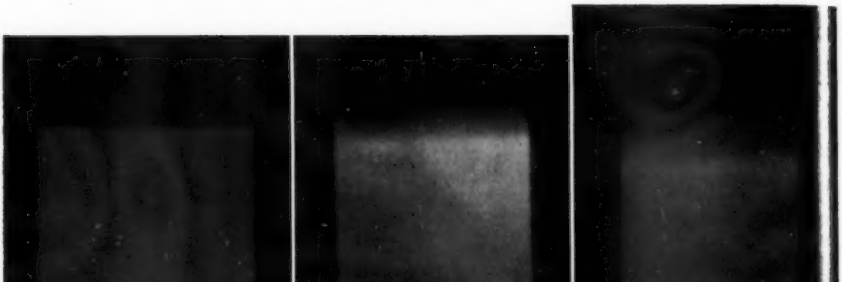
RADIATION EXPOSURE IN BODY-SECTION RADIOGRAPHY

by

F. E. STIEVE

A large number of recent investigations, which were discussed at length during the last International Congress of Radiology, have shown that at the present time diagnostic roentgen examinations still make by far the greatest contribution to the total amount of artificially-produced ionizing radiation received by the population. Results presented so far, particularly those in the reports of the National Academy of Sciences, the National Research Council, the British Medical Research Council and the International Commission for Radiological Protection (ICRP), as well as in the works of ARDRAN, HAMMER-JACOBSON, OSBORNE & SMITH, LARSSON, MOHR, and my earlier colleague SEELENTAG, predominantly contain general statistical data and measurements relating to the radiation exposure of man in routine roentgen examinations. There has been no detailed study, however, of radiations exposure during specialized forms of examination, such as tomography. For this reason Sub-Committee IV (Body-section Equipment) of the International Commission on Radiological Units and Measurements (ICRU) was given the task of carrying out such a study and reporting the findings. Within these terms of reference the following points were investigated in the various systems used for producing longitudinal body-section roentgenograms:

Based on a paper read at the 4th International Course on Stratigraphy in Genova. Submitted for publication 15 November 1960.



a b c

Fig. 1. Field size and dose distribution at the surface near the roentgen tube, for different section depths (3, 9.5 and 16 cm) in planigraphy with linear movement of tube and film. (Universal Planigraph, FFD 140 cm, pendulum angle 38°, phantom thickness 20 cm, 80 kV, 2 mm Al.)

1. The surface dose received by the body in the irradiated area;

2. The dose distribution in the body, in the area of the cone of useful radiation and its immediate surroundings;

3. The radiation received by the gonads during tomography.

Before dealing with these results in detail we shall make a few comments on the subject of technique.

Following the proposition of FRANKE, and since purely diagnostic problems were entailed, all dose values were quoted with reference to the dose received at the film (or, more accurately, at the front screen), and this was the same in all cases. As experiments by HERZ, SPIEGLER, STIEVE, WIDENMANN and others have shown, in the voltage range 50 to 150 kV, used in diagnostic work for constant film density, with intensifying screens on a calcium tungstate basis of an average intensification factor (high definition and universal screens), a constant dose is required at the front screen. The same applies to sectional radiography (WIDENMANN). During our measurements, the reference dose was 1 mr. Our experience and measurements show that nowadays, with the use of fast films and an efficient developer, the average dose can in practice be much lower.

Tests made by MORGAN, SCHOBER and myself, in the course of density calibrations of automatic exposure devices, indicate that the average density of a well-exposed film lies around 0.7 and 0.8. To produce this density a dose of 0.5 to 0.6 mr is necessary.

All dose measurements were made with a kondiometer from the physics and technology laboratories at Freiburg, operating on the Sievert condensation chamber principle. Results of measurements with this kondiometer are reproducible with an accuracy of approximately $\pm$ 3 %.

A number of 10 mm spherical chambers were used for dose measurements on the surface and within the phantom (in spite of the often irritating lack of sensitivity) since it was required to assess the dose at a large number of positions at the same time. Measurements of the dose to the gonads in cadavers and living subjects were carried out with 33 mm cylindrical chambers, as was also the dose at the film. In addition to high sensitivity, these offer the advantage of being practically independent of the wavelength on the exit side over the voltage range employed.

I. Surface dose measurements

Many studies have been made of the surface dose in the irradiated field during routine roentgen examinations, among which those of WACHSMANN and SORRENTINO should be mentioned. They were principally concerned with the incident dose as a function of voltage, wave-form, pre-filtration and focus/skin distance (FSD), and results were presented in the form of alignment charts. The dose distribution in the field of radiation is almost uniform in the case of narrow beams, such as are used in tomography. A certain dose reduction is observed towards the anode side owing to the higher selfabsorption of the anode in this direction (FUCHS, SCHAAL). Beyond the margins of the field the dose decreases very rapidly.

During section radiography of a recumbent patient, with tube and film moving, the size of the irradiated field and the dose distribution differ from those found with a stationary tube. The linear blurring in a system in which tube and film move along parallel lines is shown in Fig. 1, the layer depth being adjusted by variation of the height of the centre of rotation while the focus/film and focus/skin distances remain constant. (This system is used mainly in the Universal Planigraph and similar planigraphic equipments.) The average angle of sweep, which naturally varies with the depth of the layer, is around 38°. The dose distribution was determined from films obtained at the surface of a water phantom having the shape of a human trunk of 20 cm thickness, at section depths of 3, 9.5 and 16 cm, and with a field of 20 $\times$ 20 cm at the film. It may be seen from these three images that the area of the irradiated field becomes greater (in the direction of tube movement only) as the section plane shifts away from the tube side of the patient. Since on geometrical grounds the positioning of the patient for tomography is normally such that areas of

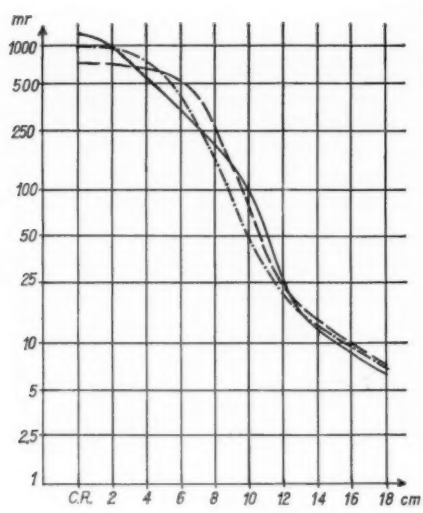


Fig. 2. Dose in mr at centre line of surface at 3 cm (——), 9.5 cm (—·—) and 16 cm (— —) layer depths.

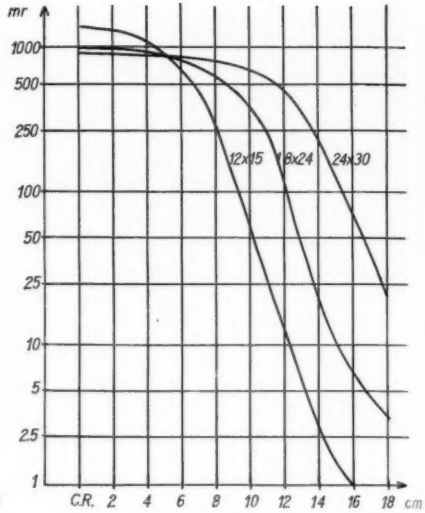


Fig. 3. Dose in mr at centre line of surface with different field sizes. Layer depth 9.5 cm.

diagnostic interest are near to the film, we have generally, when using this technique, to reckon with a more widespread skin dose than in stationary field exposures. Furthermore, there is usually a dose maximum in the centre of the field during sectional exposures.

A corresponding picture of the surface dose distribution at the same section depths are given in milliroentgens in Fig. 2 in which the region covered by the primary beam is indicated as well. When the body section is close to the tube side, the surface dose conditions of the irradiated field are the same as is customary in survey radiography. The dose fall-off outside of the primary beam is extremely steep, the dose being reduced to about one-hundredth of the incident dose at a distance of 6 cm or so from the margins of the field. The further distant the section plane is from the surface of the body, the more marked is the dose maximum in the centre of the field, with a shallow peripheral fall-off. Despite a varying fall-off of the dose in areas bordering the irradiated field, equal values are to be found at about 14 cm distance from the centre, i.e. about 6 cm from the margins of the field with the tube in median position.

In systems where tube and film move through an arc, and where the distances from focus to rotational centre and from rotational centre to film remain the same (e.g. polytome and tomograph), the distance from the rotational centre

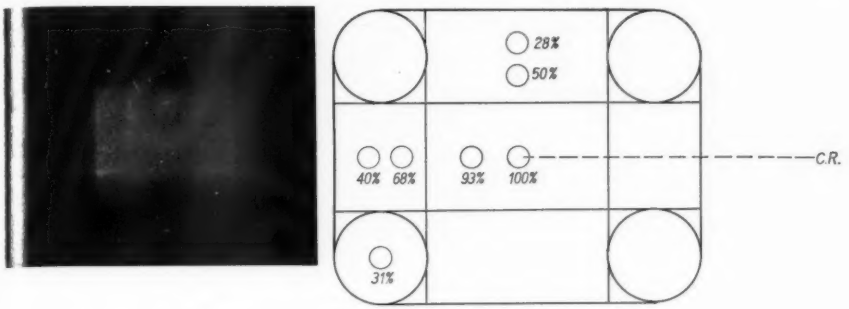


Fig. 4. Field size (a) and percentage dose distribution (b) on the body surface at circular movement of roentgen tube and film. (Polytome, FFD 140 cm, layer depth 9.5 cm, pendulum angle 44°, field size (film) 18 × 24 cm, phantom diameter 20 cm.)

to the film must be made greater than in the above mentioned system, since the subject film distance must be variable. This means that at the same layer depths the subject is nearer to the tube (and the incident dose consequently higher), but although the size of the field of radiation is the same at the film, the irradiated area of the skin of the subject is smaller. While in the centre of the field approximately similar relationships are found with both systems for the incident dose at the various section depths, the variations in surface dose obtained with the use of the latter system at different section depths will be maintained for areas outside the margins of the field. Moreover, the lack of homogeneity of the dose distribution over the whole field, with a maximum in the middle as compared to the borders of the field, is not so marked for sections nearer to the film. This might be due to the smaller variations in FSD when the tube moves through an arc.

It is self-evident that in both systems the dose distribution at the margins of the field are also influenced by the size of the angle of sweep. The greater the angle of sweep, the larger is the area of skin exposed to direct surface radiation, the smaller is the dose maximum in the centre and the steeper the dose fall-off at the margins of the field.

It should also be noted that with the same field size the mAs-value is about 30 % higher in section radiography than in survey radiography under identical conditions; this is not, however, accompanied by a corresponding increase in the average surface dose. This fact remains to be further explained. The reason can probably be sought in the greater distance from the tube to the point of incidence of the rays during part of the movement.

The surface dose distribution naturally also varies with the field size. This is shown in Fig. 3 for fields 12 × 15 cm, 18 × 24 cm and 24 × 30 cm at a

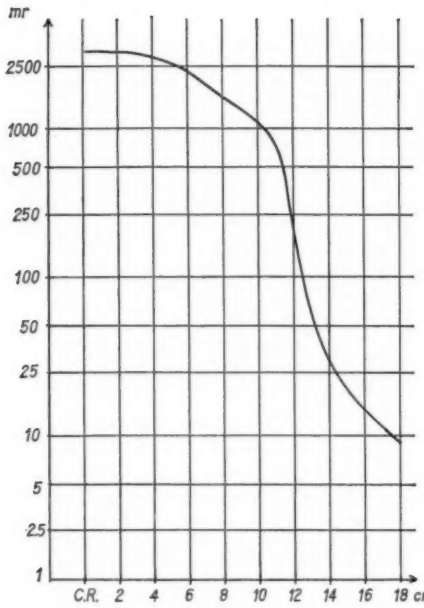


Fig. 5. Dose at centre line of surface. Other details as in fig. 4.

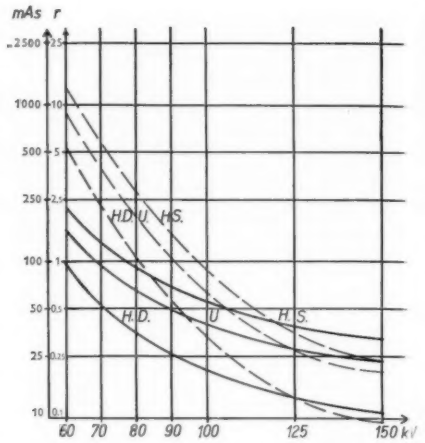


Fig. 6. Incident dose and mAs-values as functions of the kilovoltage for 3 types of intensifying screens, related to a constant film blackening D = 1.0. (Linear blurring, Universal Planigraph, FFD 140 cm, pendulum angle 38°, grid of the ratio 12.5 : 1, Kodak Regulix film, total filtration 2 mm Al.)

H. S. — High-speed intensifying screen, U — Universal screen, H. D. — High-definition screen

— — — — — — Incident dose
———————— mAs-values

layer depth of 9.5 cm and with the same angle of sweep. It may also be seen that with the same dose at the film the incident dose decreases with increasing field size as a result of the increase in radiation scatter at the film; this phenomenon was described by WILSLEY for stationary field conditions as long ago as in 1924. However, the increase in surface dose with decreasing field has its limits in section radiography. If the irradiated field x becomes smaller than double the distance d of the plane of section from the surface, times the tangent of one-half the sweep angle α (critical case when $x = 2d \cdot \operatorname{tg} \frac{\alpha}{2}$), then no surface area is constantly in the beam of radiation during the period of exposure. Although it occurs but seldom, such a condition is for instance found in section radiography of the ear, using a small field. The size of the field appears, on the other hand, as the curves run practically parallel, to have little effect on the dose fall-off in the marginal areas. Things become far more complicated when the blurring occurs in several dimensions. As an example, the dose distribution for an exposure in section radiography using a polytome with a field size 18 × 24 cm at the film, a sweep angle of 44° and circular blurring is shown i

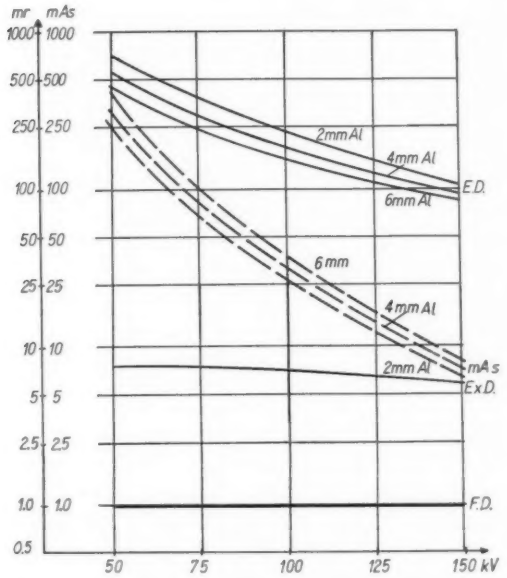


Fig. 7. Incident dose and mAs-values as functions of the kilovoltage at different filtrations. Other data as in fig. 6.

E. D. (—) Incident dose
— — — — — mAs values
Ex. D. (—) Exit dose behind phantom
F. D. — Film dose

Fig. 4a. The layer depth is again 9.5 cm. Here, too, we find a dose maximum in the centre, in all cases except the smallest field (in the sense given in the definition above). The peripheral dose fall-off is on the other hand rather irregular. The percentage surface dose distribution was measured by means of condenser chambers after the dose maxima and minima had been determined (Fig. 4b). Reductions of up to 30 % appear in the lateral sections, the total field is larger, and the dose curve in the longitudinal section (Fig. 5) is not as regular as with linear blurring. The peripheral fall-off can be seen at about 10 cm from the centre of the field, and this is also apparent in the films.

Up to now we have only been comparing the doses at one voltage. We know from numerous experiments with high voltage techniques (e.g. by FRIK, GAJEWSKI, MATTSON and WACHSMANN) that the incident dose is a function of the kilovoltage used, and varies inversely. The relations between incident dose, mAs-value and voltage in sectional exposures, using systems with parallel movements of tube and film are illustrated in Fig. 6. The FFD is 140 cm and

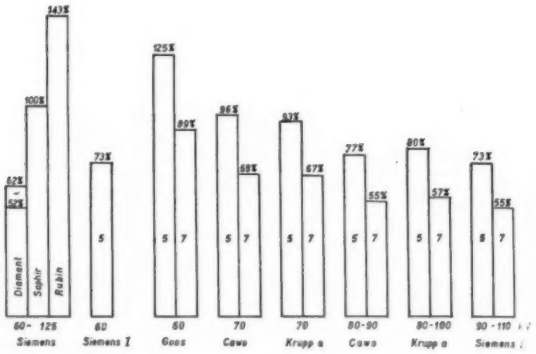


Fig. 8. Dose required at film in simultaneous multisection tomography, compared with the dose required for the same number of individual section radiographies. (Linear blurring, Universal Planigraph.)

the sweep angle 38°. In this case we did not, as elsewhere, take as a point of reference a constant dose of 1 mr but used a constant film density obtained with screens giving normal and high intensification as well as high-definition screens. While the curves for mAs and dose run almost parallel for the first and last mentioned types of screen, those obtained with the high-intensifying screen fall off steeply with higher voltage. Since universal screens call for the same dose to produce a given film density, irrespective of the voltage, this demonstrates the voltage-dependence of the intensification factor already recognized in various other studies.

An increase in prefiltration, and consequent alteration of the quality of radiation, which was once a subject of much discussion, will if used with the already comparatively strong overall filtration common nowadays (approx. 2 mm Al) bring about a reduction by 20 % of the incident dose for a supplementary filter of 2 mm Al. At the same time more exposure will be needed because of the reduction of the radiation emitted. Therefore, and in line with STANFORD's recommendations for survey radiography, a total filtration of 3 mm Al should not be exceeded in section radiography with voltages below 100 kV.

We shall finally mention one point in this connection which has been widely discussed of late: that of keeping the dose low by means of the simultaneous multisection technique. While this does offer a number of incontestable technical advantages, experiments carried out by my colleague, Miss WIDENMANN, contradict the widely-held contention that it achieves a substantial reduction of the dose (BACKLUND, GAJEWSKI, LIESS, and others). Fig. 8 shows the dose requirement of a number of commercially available multisection intensifying screen sets, and serves to bear out the findings of WIDENMANN on this point. The reference value in these experiments was the dose for an equivalent number

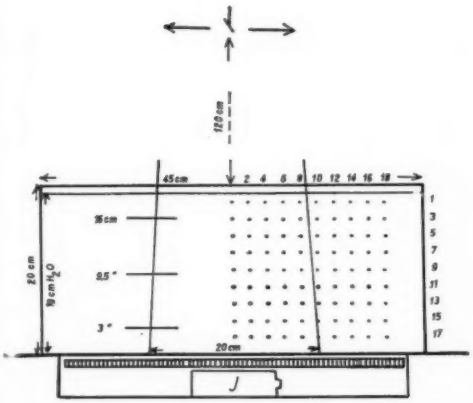


Fig. 9. Measuring scheme to determine the dose in a phantom (20 cm thick water phantom, film field size 20 × 20 cm, FFD 140 cm, reference dose: 1 mr at the film.)

J — Ionization chamber

of single exposures using a universal screen and the same kilovoltage, so that a comparison was drawn of the dose requirement behind the subject and diaphragm, in front of the first screen. The results showed that there is no very great difference between the dose needed for a simultaneous series and for the same number of single section exposures. Intensifying screen sets intended for use at higher voltages do bring about a somewhat larger reduction of dose due to the greater penetrating power of the harder rays. The fact that screen sets for simultaneous series frequently call for the use of higher voltages, and thus involve a reduction of the incident dose compared to single exposures (generally made at a lower voltage) cannot be put forward as an advantage of the multisection technique; it is rather one of the wellknown advantages of using high kilovoltages. It can, of course, equally well be used for single exposures in section radiography.

Summing up, we may say that the surface dose received during section radiography is of the same order as that received in survey radiography, although the dose is distributed over a larger irradiated field. Dose requirements are governed by the same laws as apply to general radiography.

II. Dose distribution within the body

The study of the dose distribution within the body was intended to clarify the question of the location of the dose maximum, and in particular to discover whether a dose concentration must be expected within the body, as is the case in moving field irradiation. A comparison of the radiation scatter outside the limits of the beam with that occurring under similar conditions during exposures for a general radiographic survey was also to be made. From a purely theoretical viewpoint it would not appear relevant to draw parallels, as therapy

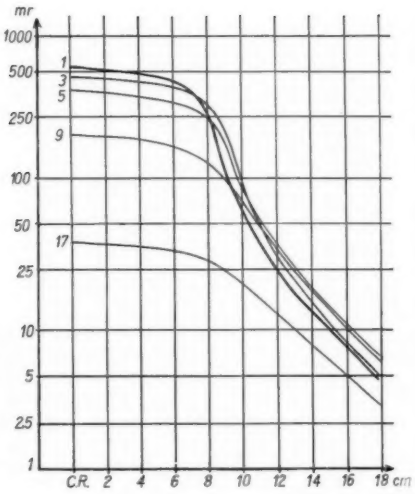


Fig. 10. Dose distribution in the phantom (20 cm of water) at different distances from the surface, referred to a constant dose of 1 mr on the film, grid of the ratio 12.5:1, 80 kV. Survey radiography.

The numbers at the dose distribution curves indicate the distance of the measuring points from the surface.

techniques involve considerably harder radiation, smaller fields and larger angles of sweep. If a correspondingly small angle were to be used in moving field therapy, a dose maximum at the skin could also be expected. A comparison was made with stationary fields of the same size, also using a grid and again taking a constant dose at the film as a reference. Measurements were made in a water phantom 20 cm thick with the Universal Planigraph, using a field of 20 × 20 cm at the film, the average sweep angle being 38°. As will be seen from Fig. 9, measurements were made at 1 cm below the water level and at 2 cm intervals down to 17 cm. Ten chambers were used in a horizontal direction, starting in the beam centre and spaced 2 cm apart; this meant that with the tube stationary, half of them were within the primary beam, and half outside.

The dose pattern with a stationary field at 80 kV is shown in Fig. 10. The dose distribution inside the cone of radiation matches the curves plotted by WACHSMANN, and is familiar from works by e.g. CEN and FRIK, JOHNS, KLOTZ, and SEELENTAG et coll.

The latter authors studied these relationships with 35 cm FSD, which gives a much sharper fall-off in intensity within the phantom. They furthermore related the incident dose to a constant exit dose, while in the present measurements account was taken also of the diaphragm factor, which alters with the voltage. This means that the exit dose, related to a constant dose behind the grid (grid ratio = 12 : 1), falls by 60 % when the voltage is raised from 50 to 150 kV. Because of the alteration of the relation incident/exit dose, and as a result of the different beam path caused by the greater distance, the pattern of the dose

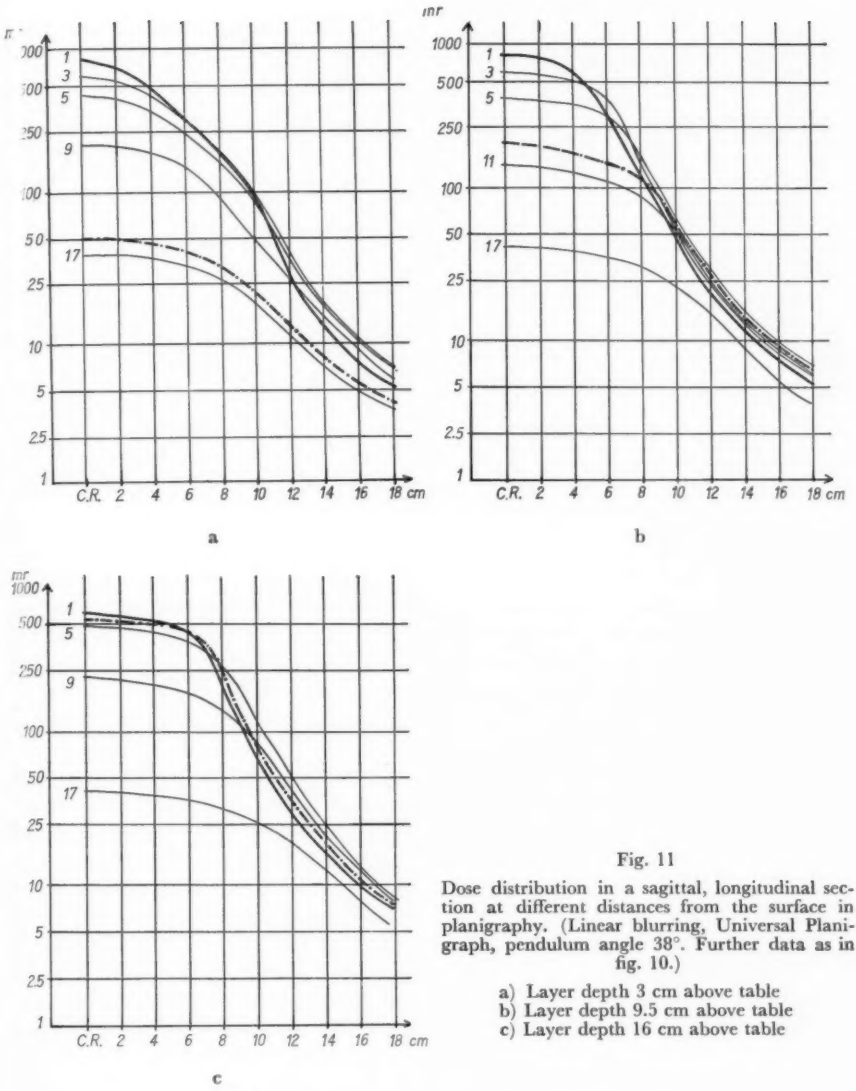


Fig. 11

Dose distribution in a sagittal, longitudinal section at different distances from the surface in planigraphy. (Linear blurring, Universal Planigraph, pendulum angle 38°. Further data as in fig. 10.)

a) Layer depth 3 cm above table
b) Layer depth 9.5 cm above table
c) Layer depth 16 cm above table

outside the area of direct radiation is also rather different. In principle, however, the curves obtained are similar to those recently presented by HAYBITTLE and MARTIN and EVANS.

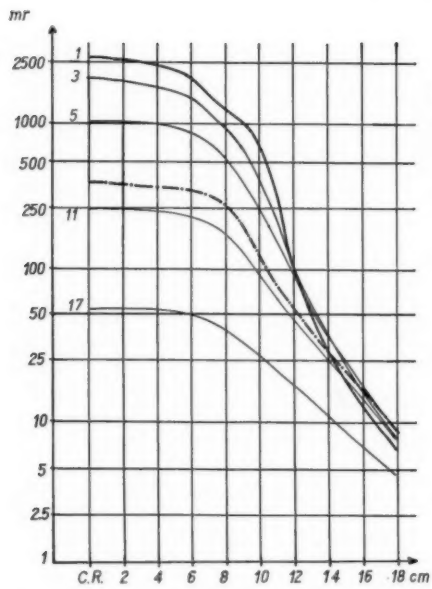


Fig. 12. Dose distribution in a sagittal, longitudinal section at different distances from the surface, with multi-dimensional blurring. (Polytome, circular blurring, pendulum angle 44°, FFD 140 cm, extrafine grid, field size 18 × 24 cm, layer depth 9.5 cm. Other data same as in fig. 10.)

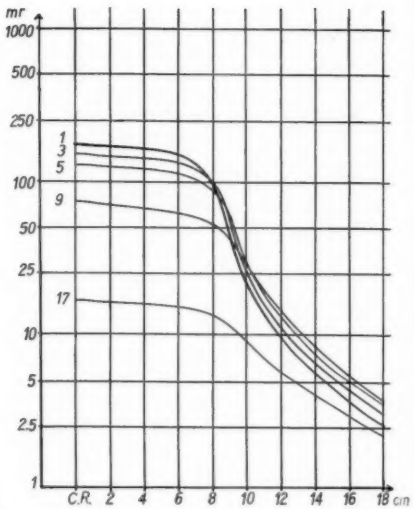


Fig. 13. Dose distribution in a sagittal, longitudinal section at different distances from the surface, with a stationary field. (Radiographic kilovoltage 130 kV. Other data same as in fig. 10.)

A comparison of the dose distribution within a phantom, using the stationary field technique, and the section technique with a Universal Planigraph with tube and film moving parallel, at section depths of 3, 9.5 and 16 cm (Fig. 11), gave the following results.

The increased dose in the centre of the field, already observed at the surface, is also found in similar fashion in the upper parts of the phantom down to approximately its middle. The greater the section depth, the greater is the dose increase at the centre of the field. Connected with this are (1) a reduction of the plateau of the incident dose curve, as seen with stationary fields to produce a peak at the 3 cm level, and (2) the different dose fall-off in surrounding areas, the curve being flatter compared to the sharper fall-off found with a stationary field. With linear blurring there is also for the various sections a dose reduction towards the margins of the field, increasing with the depth of the section, which can no doubt be mainly attributed to the difference in scattering at the centre and at the margins of the field (a phenomenon demonstrated by ZIELE

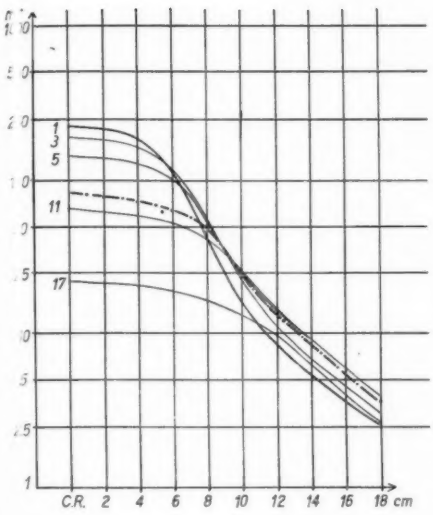


Fig. 14. Dose distribution in a sagittal, longitudinal section at different distances from the surface, linear blurring. (Radiographic kilovoltage 130 kV, layer depth 9.5 cm, other data same as in fig. 11.)

for a stationary field). The dose pattern for deeper parts of the phantom, at small section depths approximately from middle of phantom downwards, is similar to that of a stationary field; this may be due to the patterns of the primary beams being similar. At greater section depths, for which the area of primary radiation in lower parts of the phantom increases, the doses are higher, making the overall dose curve more shallow. The radiation outside the direct-ray region, at the 3 cm and 9.5 cm sections, is the same as for a stationary field both in the upper and deeper parts. The curves of the three measuring series correspond at a distance of about 12 cm. The differences between the stationary field with its sharp dose fall-off, and the sectional field with a more gentle dose curve, were most apparent in the upper parts of the phantom where they out-cancelled each other. The conditions differ completely when the section plane is near the tube side of the phantom. As a result of the shift of the beam of useful rays, and the consequent spread of the area of direct radiation to both sides in the direction of the tube sweep, the dose is then increased right out to the furthermost lateral point, measured 18 cm from the centre of the field.

The opposite is found as regards radiation scatter outside the field in the case of systems such as the polytome; in these systems it is seen to be rather greater in section areas near the film than in those further away from it. This is approximately similar to the dose at the surface. In both systems, then, the fundamental difference between stationary and moving fields is a loss of uniformity of the dose over the irradiated field at the surface and nearby areas, together

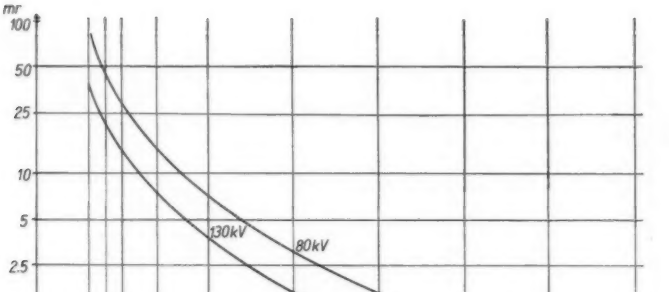


Fig. 15. Gonad dose as a function of the distance of the field margin, linear blurring in a direction parallel to the body axis. Field size 18 × 24 cm, subject thickness 20 cm, pendulum angle 38 °, FFD 140 cm, high-kV extra-fine grid of the ratio 12.5:1. The distance from field margin measured with the roentgen tube in centre position.

with an increase in the lateral dose fall-off in the upper layers of the phantom. As regards scatter, on the other hand, the dose pattern varies from that of a stationary field in the case of a planigraph type equipment only when the section planes lie near the surface, and in the case of the polytome type when they lie at depths. There is then an increase in the amount of scatter in the corresponding areas.

Using unidimensional blurring, no appreciable variation in the dose is to be expected at right angles to the direction of tube travel during sectional radiography, and this point does not warrant any discussion.

If, however, we compared the curves obtained with the Universal Planigraph and unidimensional blurring, with those from a polytome, using multidimensional blurring (Fig. 12), we see at once that the dose fall-off in the latter is greater, which may be due to the shorter distance from tube to body surface. The multidimensional movement of the tube moreover brings about a more even distribution of the dose over the area exposed to radiation, and this can be seen from the flatter curve with a steep fall-off at the margins. Since the exit dose is higher with polytome equipment than with the Universal Planigraph, by reason of the greater subject/film distance, the dose near the field is also higher.

In parts removed from the field, on the other hand, it approaches the values found with the Universal Planigraph. As I see it, this can only be explained by the multidimensional blurring.

The dose distribution at 130 kV, with the same filter (2 mm Al) as with 80 kV, is given in Fig. 13 from which the substantial reduction in dose in parts of the phantom near the tube, and the lower exit dose at the higher voltage may be seen. The improved penetration power of the harder radiation is also apparent in the shortening of the dose curve. On the other hand, a relatively small decrease in radiation scatter is observed in areas both near and removed from the edges, although (contrary to SEELENTAG's studies) there is here no absolute increase of dose with high-kV radiation compared to that with softer rays. This may be due to two circumstances: firstly, SEELENTAG based his values on a constant exit dose, while the film dose was taken as the point of reference in this study, so that depending on the grid used the exit dose at 130 kV was 37 % less than that at 80 kV; secondly, the focus/surface distance is not the same. If these factors are taken into account the results, which match those of SCHAAL, may be regarded as corroborative or complementary. In Fig. 14, values at 130 kV, using the section technique, are given. Ignoring the variations in dose caused by the movement, the same tendency as found under stationary field conditions remains.

The loss of uniformity in dose distribution over the irradiated field, which we found in section radiography as compared to a stationary field, is thus the only difference between the two techniques. There was at any rate no dose maximum in the phantom, nor any dose concentration (as is encountered in moving field therapy) at the section depths investigated.

III. Gonad doses

The investigations on radiation scatter, outside the beam of rays, and its dependence on the voltage, finally lead to a consideration of doses received by the gonads in the course of various roentgen examinations. An exhaustive treatment of this question is of course beyond the scope of the present paper, and we shall accordingly deal only with a few of the problems, and those affecting stratigraphy in particular.

Before discussing in detail the dose governing factors, we must show how much radiation is in fact received by the gonads during section radiography of various organs. The results obtained in measurements on patients during section radiography in our department over the last two years are summarized in Table 1. The measurements were made in men at points alongside the testicles and in women in the posterior vault of the vagina. The values obtained for the men may be regarded as directly corresponding with the dose to the gonads, whereas for the women they may only serve as an indication since the dose received in the vaginal vault may differ from that at the ovary,

Table 1

Doses received by the gonads in planigraphy of living patients

Organ	Dose per exposure in mr			Dose per examination in mr			80 % of all values per type of examination range between
	Mean value	Min	Max	Mean value	Min	Max	
Ear	0.03	0.007	0.12	0.57	0.007	1.32	0.1 — 0.7
Sinus	0.055	0.007	0.13	0.43	0.007	2.28	0.1 — 1.0
Apex of the lung	0.045	0.007	0.24	0.40	0.007	2.16	0.05— 0.9
Thoracic vertebr. a. p.	0.61	0.007	2.40	3.71	0.007	19.2	0,3 — 5.9
Thoracic vertebr. front	0.32	0.24	0.43	1.25	0.72	1.73	0.6 — 1.8
Gall bladder	0.37	0.03	0.78	1.58	0.12	3.36	0.3 — 2.3
Kidney	1.15	0.40	2.80	5.60	2.28	14.10	2.3 — 6.9
Lumbar vertebr. a. p.	5.5	0.42	27.0	12.03	1.68	135.0	2.5 — 50.0
Lumbar vertebr. front.	4.57	0.41	19.80	19.3	1.64	156.6	2.0 —100.0
Lungs, without apices				1.71	0.18	6.84	0.2 — 4.8

according to the type of exposure being made, and as a result of anatomical variations. It has been shown by McGregor, however, that these values are of the same order of magnitude; using salpingography he found a mean difference of 1 : 1.4 between the dose in the posterior vaginal vault and the ovary.

The dose to the gonads increases steadily, from the cranium to the pelvic region, where it reaches levels of up to 27 mr per exposure. The range of values found show clearly that in none of the examinations were the gonads exposed to direct and unattenuated radiation. Despite the large material, it was not possible statistically to discover any unequivocal relationship between the various factors which in the separate measurements were found to be responsible for the size of the gonad dose. The major factors influencing the size of the gonad dose may therefore be shown by a few examples. As the most important of these factors we must cite the distance of the margin of the field from the gonads.

The dose values measured at the testicles of a supine patient at two kilovoltages, with craniocaudal movement of the tube, at a section plane in the centre of the body, are given in Fig. 15. The figures clearly show the considerable dose reduction when the distance is increased by only a few centimetres, especially when close to the gonads. An increase from 3 cm to 6 cm, for instance, brings about a 75 % reduction of the dose, while in areas remote from the gonads, increasing the distance from, say, 20 to 23 cm makes a difference of only 20 %.

The influence of the field dimensions is shown in Fig. 16. The size of the field was varied, while the distance between the borders of the field and the gonads was kept the same. The two curves show that in spite of the fact that blurring was along the craniocaudal axis the widening of the field produced the greater deflection, and that the length of the field apparently had very little

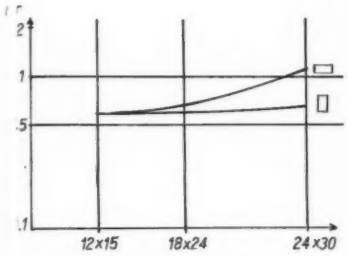


Fig. 16. Gonad dose as a function of the field size at equal distances from field margin (Universal Planigraph, pendulum angle 38°, radiographic kilovoltage 80 kV).

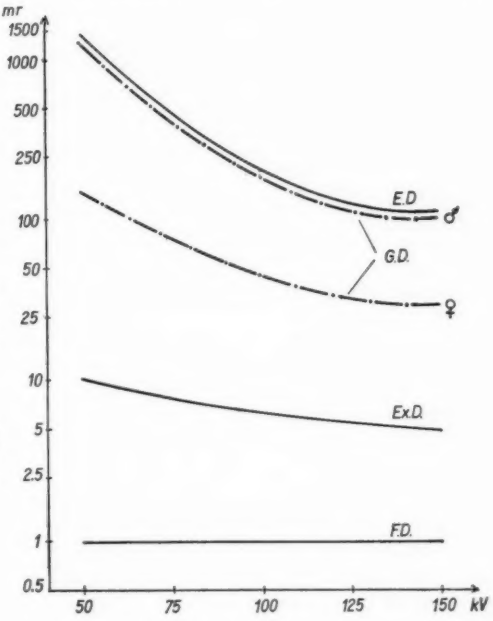


Fig. 17. Gonad dose in radiography of the pelvis, male and female, as a function of the radiographic kilovoltage. Stationary field, FFD 140 cm, field size 20 × 20 cm, subject thickness 18 cm.

Gonads positioned in the field.
E. D. — Incident dose
Ex. D. — Exit dose
G. D. — Gonad dose
F. D. — Film dose

effect. Increasing the size of the field from 15 to 24 cm brought about an increase in dose of approximately 20 %, while increasing the field size to 30 cm brought the dose up by 75 %. These figures, too, agree with those of HAYBITTLE and of MARTIN and EVANS observed under stationary field conditions.

The effect of the voltage, in exposures in which the gonads lie in the irradiated field, is illustrated in Fig. 17. Here again the patient was placed in a supine position, since this is used far more often than the prone at section radiography. It was found that for both testicles and ovaries the applied dose is reduced as the voltage increases. As is evident from Fig. 15, this also applies to the supine position when the gonads are situated at some distance from the edge of the field. It will be seen from the dose curve for the ovaries that the reduction in dose obtained at depth with an increasing voltage is not nearly so striking. There is virtually no difference between the supine and prone positions in women, but in men the values obtained are on the whole lower in the prone position, although with a grid the difference may be of the same order only as the decrease in exit dose as compared to that behind the diaphragm. Prefiltration at the tube produces a decrease in the dose to the gonads in men in the supine position. It has no effect whatsoever in the prone position, or to

Table 2

Doses received by the gonads of the same patient in survey radiography and planigraphy of lungs and hip joint (FFD 150 cm, high-kV extra-fine grid, universal intensifying screens)

	Field size	Distance field edge to gonads	kV	mAs	Dose in m
Survey radiography.....	35 × 35	23 cm	65	25	0.0
Planigraphic exposure.....	12 × 15	43 cm	65	60	0.0
	Hip joint (data as above)				
Survey radiography.....	30 × 40	3 cm	67	250	49.1
Planigraphic exposure, right hip joint.....	18 × 24	9 cm	72	300	7.8
	18 × 24	13 cm	78	300	4.1

the dose to the ovaries, since the effect of this filtration is entirely nullified in 10 cm of body tissue.

A comparison between radiation doses received during a conventional roentgen examination and at sectional radiography is presented in Table 2 for radiography of the lungs of one and the same patient under identical conditions. It may be seen that because the border of the field is closer to the gonads in the standard view of the lungs, and because the field is considerably larger, the dose to the gonads is practically the same despite the fact that the mAs value is over 50 % lower than at section radiography. If the general view of the lungs is obtained without the grid (which was here a high-kV extra-fine grid, grid ratio 12 : 1) the dose is reduced by about 85 %. The disadvantage of the planigraphic technique is evident, however, when we remember that a minimum of 4 to 6 exposures per examination will be involved, although even then the absolute dose level is still insignificant.

If on the other hand we compare a general view of the pelvis with a sectional view of the hip joint, the immediate proximity of the gonads means that the smallness of the field (and the consequently greater gonad/field-border distance) is greatly to the advantage of the section view; so much so, in fact, that 7 to 12 well-masked section exposures are needed to make up the gonad dose from a single general view of the pelvis.

If, finally, we consider to which extent section radiography under present conditions and henceforth may be justified we must bear in mind three important facts. Firstly, sectional views are normally made only when the clinical and radiologic examinations have provided a sufficient indication. Unlike the routine roentgen examinations section radiography is performed for a specific purpose and as such generally of great value both in diagnosis and therapy. Secondly, they cover only part of the area included in survey radiography so that direct radiation is virtually never received by the gonads. Thirdly, even in large hospitals with prodominantly clinical cases, this type of examination forms only a small part of the total; in our department the sectional views amount to

about 3.5 % of the overall number of exposures, the majority of these being of the lungs. Section radiography of the bones and abdomen is of much smaller proportion. In any case, the examinations performed with the use of the sectional technique therefore mainly entail those in which the dose to the gonads is very small. We can accordingly with confidence conclude that the somatic and genetic effects connected with section radiography, assuming of course technical competence in its performance, play no significant part in the exposure of man to ionizing radiation.

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SUMMARY

The radiation dose at section radiography (tomography) has been determined by means of measurements on phantoms, cadavers and living subjects. Both in the area of direct radiation and in surrounding areas the dose, with slightly varying distribution, is of the same order as in survey radiography under identical conditions. Dose requirements in both sectional and standard radiography are governed by the same rules. The statistical assessment of the results of measurements of gonad doses in patients indicates that in a properly executed examination the radiation received during tomography makes only an insignificant contribution to the total radiation exposure of the population during diagnostic roentgen examinations.

ZUSAMMENFASSUNG

Auf Grund von Messungen an Phantomen, an Leichen und am Lebenden wurde dosimetrisch die Strahlenbelastung bei Schichtaufnahmen bestimmt. Sowohl im direkt bestrahlten Gebiet als auch in dessen Umgebung liegt die Dosis bei etwas geänderter Verteilung etwa in derselben Grössenordnung wie bei Übersichtsaufnahmen unter gleichen Bedingungen. Der Dosisbedarf unterliegt bei Schicht- und Standardaufnahmen den gleichen Gesetzmässigkeiten. Auch die statistische Auswertung der Messergebnisse der Gonadendosen am Patienten zeigt, dass die mit der Schichtaufnahme verbundene Strahlenbelastung bei richtiger Durchführung der Untersuchung die Gesamtbelastung der Bevölkerung durch röntgendiagnostische Massnahmen nur unwesentlich beeinflusst.

RÉSUMÉ

La dose de rayonnement reçue au cours de la tomographie a été déterminée par des mesures sur des fantômes, sur des cadavres et sur des sujets vivants. Aussi bien dans la surface d'irradiation directe que dans les régions voisines, la dose reçue est du même ordre, avec de petites différences de distribution, que celle reçue pour une radiographie dans les mêmes

conditions. Les règles fixant les doses admissibles sont les mêmes en tomographie qu'en radiographie simple. L'étude statistique des résultats de mesures de doses-gonades sur les malades indique qu'avec un examen exécuté convenablement, la dose reçue au cours de la tomographie ne contribue que de façon insignifiante à l'irradiation totale reçue par la population du fait des examens radiologiques.

REFERENCES

ARDRAN, G. M. und CROOKS, H. E.: Gonad radiation dose from diagnostic procedures. Brit. J. Radiol. 30 (1957), 295.

BACKLUND, V.: Über die Technik der simultanen Telefilmplanigraphie. Acta radiol. (1956) Suppl. 137.

CEN, M. and FRIK, W.: Raumdosis und Keimdrüsendosis bei verschiedenen Strahlenqualitäten in der Röntgendiagnostik. Fortschr. Röntgenstr. 88 (1958), 465.

FRANKE, H.: Die Norm im Röntgenbild. Fortschr. Röntgenstr. 44 (1931), 691.

GAJEWSKI, H.: Physikalische und aufnahmetechnische Gesichtspunkte bei Röntgenaufnahmen mit hohen Spannungen. Fortschr. Röntgenstr. 80 (1954), 642.

— Grundlagen und Anwendungsmöglichkeiten des Simultan-Schicht-Verfahrens. Röntgen u. Lab. Prax. 9 (1956), 265.

HAMMER-JACOBSEN, E.: Gonadedoser i diagnostisk radiologi (Danish). Ugeskr. Laeg. 119 (1957), 279.

HARTUNG, K.: Zur Frage der Strahlenbelastung und des Strahlenschutzes in der pädiatrischen Röntgendiagnostik. Med. Klin. 53 (1958), 1209.

HAYBITTLE, J. L.: The effect of field size on the dose of the patient in diagnostic radiology. Brit. J. Radiol. 30 (1957), 663.

HERZ, R. H.: The spectral quantum- and energy-efficiency of calcium tungstate x-ray intensifying screens. Brit. J. appl. Phys. 7 (1956), 182.

ICRP-Report: Exposure of man to ionizing radiation arising from medical procedures. Phys. in Med. Biol. 2 (1957), 107.

ICRU-Report: Report of the International commission on Radiological Units and Measurements. Handbook 62, U. S. Dept. of Commerce, N. B. S. Washington D. C. 1956.

JOHNS, H. E.: X-rays and teleisotope γ-rays. *In:* Hine and Brownell: Radiation dosimetry, p. 532, Academic Press, New York 1956.

KLOTZ, E. und SEELENTAG, W.: Untersuchungen zur Belastung der Keimdrüsen durch Hartstrahldiagnostik. Fortschr. Röntgenstr. 89 (1958), 92.

LARSSON, L.-E.: Radiation doses to the gonads of patients in Swedish roentgen diagnostics. Acta radiol. (1958) Suppl. 157.

LAUGHLIN, J. S. and PULLMAN, I.: Gonadal dose produced by the medical use of x-rays. *In:* The biological effects of atomic radiation. Nat. Acad. Sci., Washington D. C. 1957.

LIESS, G.: Das Simultanschichtverfahren und seine Anwendung in der Röntgendiagnostik. Dtsch. Gesundheith.-Wes. 21 (1956), 693.

MARTIN, J. H. and EVANS, A.: Radiation outside the defined field. Brit. J. Radiol. 32 (1959), 7.

MATTSSON, O.: Practical photographic problems in radiography. With special reference to high-voltage technique. Acta radiol. (1955), Suppl. 120.

MOHR, H.: Über Messung der Gonadendosis bei Patienten in der Röntgendiagnostik. Strahlenther. 106 (1958), 80.

MORGAN, R. H.: The control of diagnostic quality in roentgenograms of the chest. Amer. J. Roentgenol. 50 (1943), 149.

OSBORN, S. B. and SMITH, E. E.: The genetically significant radiation dose from the diagnostic use of x-rays in England and Wales. Lancet 1956: I, p. 949.

SCHAAL, A.: Beitrag zur Frage der Streustrahlenbelastung des Patienten bei Röhrenspannungen von 60 bis 180 kV. Fortschr. Röntgenstr. 90 (1959), 247.

CHOBER, H.: Die Abhängigkeit der Durchschnittsschwärzung bei Röntgenbildern vom gewählten Format und von der gestellten Aufgabe. Vortrag IX. Internat. Congr. f. Radiologie in München 1959.

EELENTAG, W.: Zur Frage der genetischen Belastung der Bevölkerung durch die Anwendung ionisierender Strahlen in der Medizin. Teil I bis IV. Strahlenther. 104 (1957), 182; 105 (1958), 169; 107 (1958), 337, 537.

– und KLOTZ, E.: Die Streustrahlung im Körper bei Strahlenqualitäten von 50 bis 200 kV Erzeugerspannung. Strahlenther. 108 (1959), 112.

IEVERT, R.: Eine Methode zur Messung von Röntgen-, Radium- und Ultrastrahlen nebst einigen Untersuchungen über die Anwendbarkeit derselben in Physik und Medizin. Acta radiol. (1932) Suppl. 14.

ORRENTINO, J. and YALOW, R.: A nomogram for dose determinations in diagnostic roentgenology. Radiology 50 (1950), 748.

PIEGLER, G.: Das Röntgenbild — dosimetrisch betrachtet. Fortschr. Röntgenstr. 80 (1954), 754.

TANFORD, R. W.: The use of cones and filters to reduce patient dosage in diagnostic radiology. Brit. J. Radiol. 30 (1957), 497.

TIEVE, F. E.: Untersuchungen über das Wirkungsprinzip von Belichtungsautomaten für Röntgenaufnahmen. Fortschr. Röntgenstr. 85 (1956), 491.

THE HAZARD TO MAN OF NUCLEAR AND ALLIED RADIATION. British Medical Research Council; London 1956.

WACHSMANN, F.: Dosisbelastung des Patienten bei röntgenologischen Untersuchungen. Fortschr. Röntgenstr. 75 (1951), 728.

— BREUER, K. und BUCHHEIM, E.: Grundlagen und Ergebnisse der Hartstrahltechnik. Fortschr. Röntgenstr. 76 (1952), 147.

WIDENMANN, L.: Untersuchungen über die Abhängigkeit der Filmschwärzung mit handelsüblichen Verstärkerfolien von der Strahlenqualität. Fortschr. Röntgenstr. 87 (1957), 386.

— Vergleichende Untersuchungen über Bildqualität und Dosisbedarf bei Simultan- und Einzelschichtaufnahmen. Fortschr. Röntgenstr. 89 (1958), 613.

WILSLEY, R. B.: The intensity of scattered x-rays in radiography. Amer. J. Roentgenol. 8 (1921), 328.

ZIELER, E.: Äquivalente Aufnahmebedingungen in der Röntgendiagnostik. Acta radiol. 43 (1955), 393.

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BEHAVIOR OF I^{131} FOLLOWING ITS INHALATION AS A VAPOR AND AS A PARTICLE

by

D. H. WILLARD and W. J. BAIR

One of the potential hazards associated with certain atomic energy facilities is the release of I^{131} to the atmosphere from a reactor or during the separation of plutonium from fission products and uranium. Considerable effort has been expended to define the hazards of ingested I^{131} (BUSTAD et coll. 1957) but few data are available on the entry of I^{131} into the body by breathing air containing I^{131} either as a vapor or as a particle. Because of the extreme solubility of I^{131} vapor, it is usually assumed that whether I^{131} enters the blood through the lungs or through the gastrointestinal tract, its behavior and effects will be the same. If inhaled as an insoluble particle it would be expected that I^{131} would tend to remain in the lung longer and not be translocated immediately to thyroid tissue. However, for purposes of establishing maximum permissible limits, it is helpful to have experimentally determined deposition, retention, and translocation data. This paper reports data obtained using mice and sheep breathing air containing 'very soluble' I^{131} vapor and air containing 'insoluble' AgI^{131} particles. Iodine vapor is known to be rapidly absorbed by animal tissues, and silver iodide is one of the most water-insoluble iodine compounds.

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Table 1

Experimental design of exposures

	Inhalation			Additional routes of administration	
	Number of animals	Exposure time (minutes)	Aerosol concentration (μC/cc)	Number of animals	Route
$_2^{131}$	80 mice	30	2.3×10^{-2}	—	—
	3 sheep	20	1.0×10^{-3}	—	—
$\backslash aI^{131}$	—	—	—	1 sheep	Intragastric
$\backslash gI^{131}$	80 mice	120	3.0×10^{-2}	1 sheep	Intragastric
	3 sheep	30	7.8×10^{-3}	1 sheep	Subcutaneous
				1 sheep	Intraperitoneal

Methods

Mouse exposures. The experimental design is given in Table 1. Eighty two-month-old female BAF_1 mice, obtained from the Jackson Memorial Laboratory, were exposed to I^{131} vapor and 80 were exposed to an aerosol of AgI^{131} particles. Immediately following exposure and at intervals up to 90 hours after exposure, groups of 10 mice were killed for radiochemical assay of all tissues. The tissues were digested with a 0.25 N sodium hydroxide solution, and aliquots were plated and counted with an end-window Geiger-Müller tube. The method for exposing mice to radioactive aerosols was described in detail by WILLARD et coll. (1958). Briefly, mice were individually placed, head first, in 50 ml conical centrifuge tubes with the bottom one-half inch (12.6 mm) removed to give a three-eighths inch (9.5 mm) opening. The tubes, plugged with tissue paper and stoppered, were inserted into ports drilled into the side of a verticle exposure chamber constructed of 16 inches (407 mm) of 8 inch (204 mm) (O. D.) lucite pipe. The chamber held 84 tubes in 7 rows of 12 each. The aerosol was admitted at the top and exhausted at the bottom through a 0.5 N sodium hydroxide scrubber to remove I^{131} vapor and through an electrostatic precipitator to remove AgI^{131} particles before the air was exhausted from the building. Samples of the aerosol in the chamber were collected by pulling known quantities of air through four small sodium hydroxide scrubbers for I^{131} vapor or through four millipore filters (type AA, manufactured by the Millipore Filter Corporation) for AgI^{131} particles. Radiochemical assay of the scrubbers and filters gave the average concentration of I^{131} in the chamber during the exposure period. Fig. 1 is a photograph of the exposure chamber within a glove box.

Sheep exposures. Six, nine-month-old purebred male Suffolk sheep weighing 60 to 70 kilograms, were used in this experiment. Their diet consisted of chopped alfalfa and a grain mixture fed twice daily (BUSTAD 1952). The sheep were kept in metabolism cages and were monitored by duplicate neck counts with complete repositioning of collar each time the animal was monitored. A thyroid monitoring device, specifically designed for sheep, was used to detect the gamma radiation emanating from the gland region (HERDE et coll. 1952). Background count was determined by placing the monitoring instrument on the rump of the animals.

Sheep were exposed by a method similar to that used for mice except that the I^{131} aerosol was drawn into a plastic bag which was contained in a round cardboard shipping crate 28 inches (712 mm) in diameter. A mask was attached to the bag through a lucite cover on the container with a one-inch (2.54 mm) pipe fitting, and a three-way valve. Sheep inhaled the aerosol from the bag and exhaled into a sodium hydroxide trap.

Parenteral injections were made using a 10 ml syringe fitted with a 22 gage needle, the

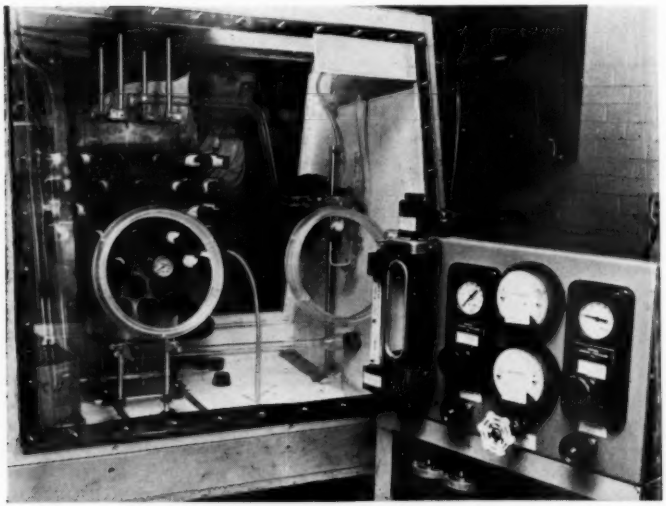

Fig. 1. Mouse exposure chamber within a glove box.

intraperitoneal injection being given in the paralumbar fossa and the subcutaneous injection given in the inguinal region. Oral administrations were made by feeding sheep food pellets containing NaI^{131}.

Generation of iodine vapor. Iodine vapor was generated by the method of DAILEY (1945) and modified by SELDERS (1956). All glassware and the exposure chamber were treated with dri-film (dimethyldichlorsilane, General Electric Company). A generator was fashioned from a 100 ml test tube, Fig. 2. Four ml H_2O, 1.25 ml NaI^{131} (14.3 mC — purchased from the Oak Ridge National Laboratory), 6 g $FeSO_4$ and 0.5 ml H_2SO_4 were placed in the generator. With the generator connected to the exposure chamber and 500 cc air per minute being bubbled through the mixture in the generator, one ml H_2O_2 was added to start the release of iodine vapor. After 30 minutes the reaction was stopped by the addition of one millilitre saturated sodium bisulfide.

AgI^{131} particles. AgI^{131} particles were prepared by adding 2 mg of I as NaI, 1.25 ml NaI^{131} (15.57 mC), and 0.1 ml 0.1 N $AgNO_3$ to 23 ml H_2O in a 125 Erlenmeyer flask on a magnetic stirrer. After being stirred for 15 minutes, at room temperature, the suspension was filtered through a millipore filter. After addition of 0.1 ml $AgNO_3$ the filtrate was stirred for one hour longer, then filtered through the same millipore filter. The filtrate was discarded and the filter containing the precipitate was placed in a 50 ml conical centrifuge tube. The millipore filter was dissolved by washing and centrifuging twice with 3 ml acetone. The precipitate was then washed with water and suspended in 20 ml of 0.1 per cent aqueous polypropyleneglycolethylene oxide polymer (Wyandotte Chemical Company) solution. Before transfer to the aerosol generator, the particles were placed on an ultrasonic generator for several hours to break up aggregates. The solubility of AgI^{131} prepared in this manner was 2 per cent in H_2O and 34 per cent in Ringer's solution at 37° C. The generator used to

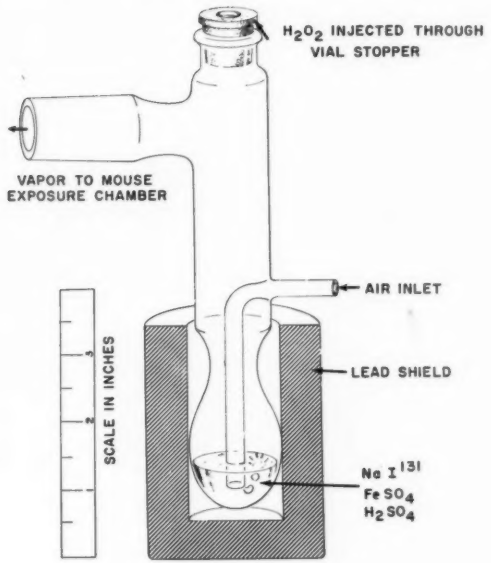

Fig. 2. I^{131} vapor generator.

atomize AgI^{131} particles from the Pluronics suspension was described by WILLARD et coll. (1958). With this generator dispersal of the particles in a fog was effected by forcing air at 20 psi through an orifice (No. 80 size hole) in the side of a 12 gage spinal needle at the end and inserted into the suspension to a level placing the orifice just above the surface of the suspension. The fog was then passed into the exposure chamber. The particles collected on millipore filters from the exposure chamber were sized by electron microscope examination. The mean size was about 0.25 microns by count.

Results

Mouse experiments — I^{131} vapor. The average concentration of I^{131} in the chamber during the 30 minute exposure period was 2.2×10^{-2} μC/cc air. It was assumed that mice inhaled an average of 25 cc air per minute (WADC Technical Report, 1956 and GUYTON 1947). A similar tidal volume was observed in this laboratory. It was estimated, then, that 16 μC of I^{131} were inhaled by each mouse. About 60 per cent of this was deposited in the mouse and the remainder apparently exhaled. The distribution of I^{131} vapor in the mouse is given in Fig. 3. The per cent of the I^{131} inhaled that was present in each tissue is shown as a function of time after exposure. The rapid initial transfer of I^{131} to the circulatory system not only from the lung but from the upper respiratory and the gastrointestinal tracts is indicated by the high

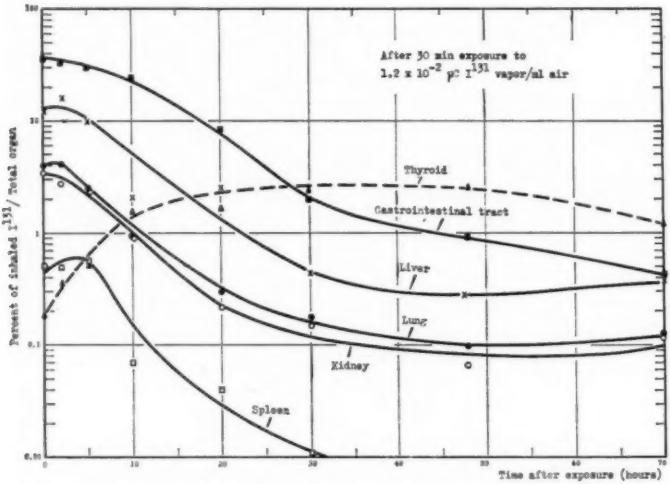

Fig. 3. Distribution of I^{131} in mice after inhalation of I^{131} vapor. After 30 min exposure to 1.2×10^{-2} μC I^{131} vapor/cc air.

percentages present in liver, kidney, and spleen. As the level in these tissues and in lung and gastrointestinal tract decreased, the quantity in thyroid increased. The maximum level in the thyroid was 0.4 μC and occurred about 30 hours after exposure. This was about 2.5 per cent of the total quantity of I^{131} or about 4 per cent of the total deposited. Forty-eight hours after exposure the quantity in thyroid began to decrease. The apparent clearance of I^{131} from lung (half-time of two to four hours) is in reality probably the rate of clearance of I^{131} from blood because similar clearance rates were observed for liver, kidney, and gastrointestinal tract. The actual clearance from lung was undoubtedly almost instantaneous.

AgI^{131} particles. The average concentration of AgI^{131} in the chamber during the two-hour exposure period was 3×10^{-3} μC/cc of air. The total quantity inhaled per mouse, assuming an average of 25 cc of air breathed per minute, was 9 μC. Of this only about one μC or 12 per cent was deposited and the remainder probably exhaled. The distribution of I^{131} in the mouse after inhalation of AgI^{131} particles is shown in Fig. 4. About 2 per cent of the total quantity breathed was in the lung at the end of the exposure period, about 6 per cent in the gastrointestinal tract and 2 per cent in liver. Again the rapid transfer of I^{131} to blood was indicated by the early presence in spleen, kidney, adrenals, and liver. The apparent four to six hours half-time required for clearance of I^{131} from the lung was again probably the clearance of I^{131} from

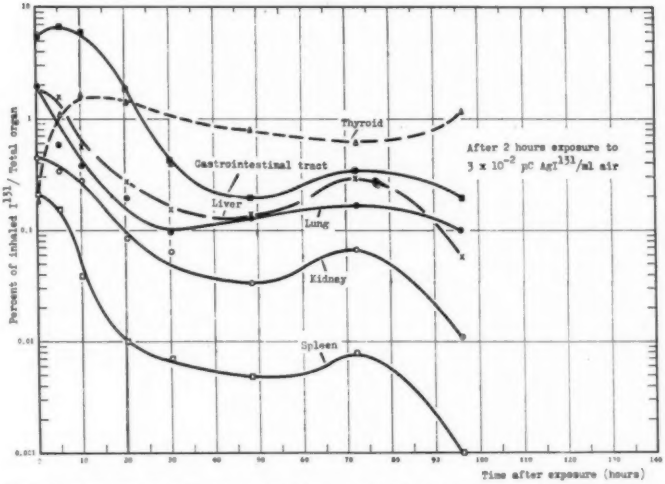

Fig. 4. Distribution of I^{131} after inhalation of AgI^{131}. After 2 hrs exposure to 3 × 10^{-3} μC AgI^{131}/cc air.

blood. The maximum level in thyroid was attained after 10 hours and was about 2 per cent of the total quantity inhaled.

For comparison of the distribution of I^{131} in tissues after inhalation of I^{131} vapor with distribution after inhalation of AgI^{131} particles, the percentage of the total body burden per tissue is plotted against time in Fig. 5. In these calculations the eviscerated carcass was excluded to eliminate errors due to surface contamination of the fur. Data for spleen, adrenals, and ovaries are not included because these organs contained a relatively small per cent of the total I^{131}. The maximum amount in the thyroid was 60 per cent of the body burden and occurred about 50 hours after inhalation of either I^{131} vapor or 'insoluble' AgI particles.

Sheep experiments. Three sheep were exposed to I^{131} vapor and three to AgI^{131} particles via the respiratory route. The total microcuries of I^{131} inhaled (but not necessarily deposited) were estimated from the concentration in the chamber, the duration of the exposure and the average minute volume determined during many pre-I^{131} exposure test runs. The I^{131} inhaled varied from 180 to 290 μC for three sheep (Table 2). The quantity of I^{131} present in the thyroid at the time of maximum uptake (20 to 35 hours after exposure) varied from 3 to about 8 per cent of the total inhaled. The AgI^{131} data for sheep were less certain. Due to difficulties encountered in the collection of aerosol samples, estimates of the I^{131} inhaled as AgI^{131} particles may be in

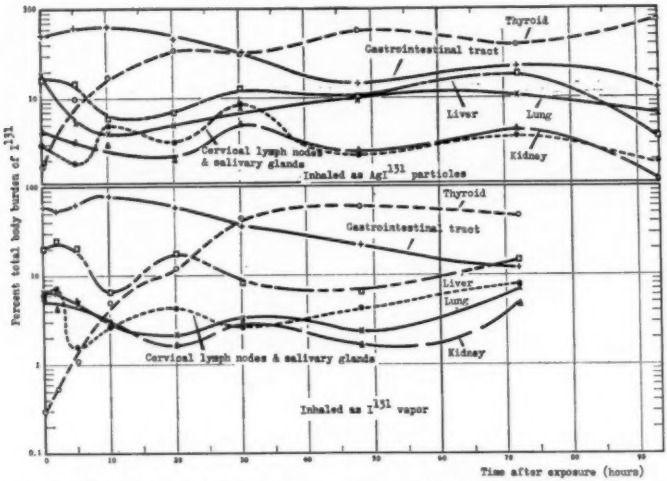

Fig. 5. Distribution of I^{131} in the mouse after inhalation of AgI^{131} particles.

error. In one sheep, about 2 per cent of the I^{131} inhaled was in the thyroid 20 hours after exposure. The time of maximum uptake by thyroid varied from 20 to 24 hours, which was less than when I^{131} vapor was inhaled.

To test the relative behavior of 'soluble' and 'insoluble' forms of I^{131}, NaI^{131} was given orally, and AgI^{131} was given orally, subcutaneously, and intraperitoneally to four of the same sheep used in inhalation experiments. In all of these, the time for maximum uptake (40 to 60 per cent of the I^{131} given) in thyroid was 28 to 34 hours. The biological half-life was four and one-half to seven days, and except for one sheep, was about the same that was observed after inhalation.

Discussion

DAILEY (1945), using anesthetized rats breathing I^{131} through tubes inserted into the tracheas, found that 10 per cent of the inhaled I^{131} was deposited during a 30 minute exposure. Of that deposited, only 5 per cent was in the lung of rats killed immediately after the exposure. In this study, where the exposure was not confined to the lungs, about 60 per cent of the I^{131} inhaled was deposited after a 30-minute exposure. Only about 4 per cent of that inhaled was in the lungs. This was about 7 per cent of the whole-body burden, or of the total amount retained.

DAILEY also found that the thyroid reached a maximum of about 10 per cent of the deposited dose of I^{131} after 48 hours. In the present study with

Table 2

Thyroid uptake of I^{131} in sheep

Sheep number	Thyroid weight* (grams)	By inhalation** Aerosol	μC I^{131} inhaled	Maximum μC I^{131} in thyroid	Time of maximum (hours)	Per cent of inhaled	Biological half-life (days)	By other routes I^{131} compound and route of admin.	μC I^{131} given	Maximum μC I^{131} in thyroid	Time of maximum (hours)	Per cent of dose	Biological half-life (days)
6	7.4	I^{131}	180	7.3	20	4.1	4-1/2	NaI^{131} (oral)	25	14	28	56	4-1/2
7	4.9	I^{131}	290	22	35	7.5	6-1/2	—					
27	6.6	I^{131}	260	7.5	35	2.9	4-1/2	AgI^{131} (oral)	46	22	34	48	6-1/2
5	3.4	AgI^{131}	9.6***	6.4	20	?	6-1/2	—					
96	7.0	AgI^{131}	610***	10	20	1.7	4-1/2	AgI^{131} (Sub-Q.)	46	19	28	41	4-1/2
97	8.5	AgI^{131}	24***	7.4	24	?	6-1/2	AgI^{131} (I. P.)	46	22	34	47	7

* At conclusion of the experiment.

** Aerosol concentrations were 1×10^{-3} μC/cc I^{131} vapor and 7.8×10^{-3} μC AgI^{131} particles.

*** These values may be in error due to difficulties in collecting representative samples of the aerosols.

mice, the level of I^{131} in the thyroid reached a maximum of 4 per cent of the deposited dose after 30 hours. In view of the many factors which affect thyroid uptake of iodine, one of the most important being the total iodine content of the diet, the results of the two studies are not in marked disagreement. No attempt to control the iodine intake via the diet was made in either study, although it was known that the daily iodine intake for sheep was 0.3 to 0.5 mg. DAILEY administered I^{131} by intratracheal tube, thus limiting the area of absorption to tracheal and pulmonary tissue. The absorption of I^{131} may be more rapid and more complete in pulmonary tissues than in the upper respiratory and gastrointestinal tract. In this study a large fraction of the I^{131} was deposited in the upper respiratory passages and gastrointestinal tract. This might account for the absorption as being less than reported by DAILEY. As in this study, DAILEY found the apparent clearance rate of I^{131} from lung to be almost identical to that from the rest of the carcass and concluded that the observed lung activity was really blood activity. In both of these inhalation studies, the percentage of I^{131} reaching the thyroid was lower than the 15 to 80 per cent reported after other routes of administration (BUSTAD et coll. 1957).

The values estimated for the total quantity of I^{131} inhaled, but not necessarily deposited, can reflect several possible errors. These include the assumed value for the minute volume and the measurement of the average concen-

tration of I^{131} in the inhaled air. It is unlikely, however, that the estimated percentage of inhaled I^{131} that was accumulated in the thyroid following inhalation of I^{131} vapor (2.5 per cent in mice and 3 to 7.5 per cent in sheep) was in error more than a factor of two. The total deposition of inhaled AgI^{13} particles (12 per cent in mice), however, was considerably lower than the 60 to 80 per cent observed in mice after inhalation of $Pu^{239}O_2$ or $Ru^{106}O_2$ (BAIR 1960). Neglecting the possibility of errors occurring in collecting and counting the AgI^{131} particles or in the assumed minute volume, the difference may be due to particle shape. The mean diameter of particles was between 0.2 and 0.3 microns which was comparable to the $Ru^{106}O_2$ and $Pu^{239}O_2$. Under electron microscopic examination the AgI^{131} particles appeared as small spheres. $Ru^{106}O_2$ particles were three-dimensional chain aggregates and $Pu^{239}O_2$ particles were aggregates of cubes.

The results with sheep were in general agreement with those with mice. Maximum thyroid uptake of I^{131} occurred sooner after exposure to AgI^{131} (10 hours in mice and 20 to 24 hours in sheep) than for I^{131} vapor (30 hours in mice and up to 35 hours in sheep).

The biological half-lives for iodine in the thyroids of the nine-month-old sheep used in this study ranged from four and one-half to seven days. Values of 14 to 46 days were observed in earlier studies in which ten-month-old sheep were fed food pellets containing I^{131} (HEALY et coll. 1957). The reason for this difference is unknown since dietary iodine levels were the same for the sheep used in both studies. It was unexpected that the translocation from the site of injection of both subcutaneous and intraperitoneal particles would be as rapid as from inhaled or ingested vapors or particles. This rapid translocation further emphasizes the unusual properties of the body fluids in the solubilization of inert particles and their immediate transport to specific organs or tissues. The apparent tissue solubility of AgI was unexpected even though the solubility of AgI used in these experiments was 2 per cent in H_2O and 34 per cent in Ringer's solution. After inhalation there was little difference between the absorption of I^{131} administered as a gas and as silver iodide particles. Similar rapid translocation was observed following introduction of $Sr^{90}SO_4$ into dog's lung (SMITH et coll. 1959). However, $SrSO_4$ is much more soluble in water and acids than is AgI. These results also emphasize the unusual properties of body fluids and show that one cannot always predict what will occur in body tissues on the basis of tests with pure solvents alone.

Conclusions

These studies confirmed the often observed rapid absorption of I^{131} by tissue, occurring even when given in a relatively insoluble form, AgI. In mice at least 60 per cent of the inhaled I^{131} vapor was deposited. Twenty to 40 hours later the thyroid contained 2.5 per cent of the total inhaled. This may

have been as high as 7.5 per cent in sheep. These results are not in complete agreement with the data tabulated by the International Commission on Radiological Protection (1959). Seventy-five per cent of the quantity inhaled is expected to be deposited in the whole body and 23 per cent will be translocated to thyroid tissue.

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SUMMARY

In mice the maximum thyroid uptake occurred 20 to 30 hours after inhalation of I^{131}: 2.5 per cent of total I^{131} inhaled as vapor and 1.6 per cent of the total inhaled as 'insoluble' AgI^{131}. This amount represented 60 per cent of the total body burden. In sheep the maximum thyroid uptake occurred between 20 and 35 hours after inhalation, oral, subcutaneous or intraperitoneal administration. Two to 7 per cent of inhaled I^{131} appeared in thyroid compared with 40 and 60 per cent of that given by other routes. The results with inhaled AgI^{131} particles emphasize the unusual properties of the body fluids in solubilizing relatively 'insoluble' particles.

ZUSAMMENFASSUNG

Bei Mäusen trat die maximale Aufnahme in der Schilddrüse 20—30 Stunden nach Inhalation von J^{131} auf. 2,5 % des totalen J^{131} wurde als Gas inhaliert und 1,6 % der gesamten Jodmenge wurde als „unlösliches" AgJ^{131} inhaliert. Diese Ziffern repräsentierten 60 % der Totalbestrahlung. Bei Schafen trat die maximale Aufnahme in der Thyreoidea nach Inhalation, oraler, subkutaner oder intraperitonealer Administrierung nach 20—35 Stunden auf. 2 %—7 % des inhalierten J^{131} erschienen in der Thyreoidea verglichen mit 40—60 % des auf andere Weise administrierten Jodes. Die Ergebnisse mit inhalierten AgJ^{131}-Partikeln zeigen deutlich die ungewöhnlichen Eigenschaften der Körperflüssigkeiten auf, relativ „unlösliche" Partikel auflösen zu können.

RÉSUMÉ

La fixation thyroïdienne maximale se produit chez des souris entre 20 et 30 heures après l'inhalation de I^{131}: 2,5 pour cent du total de I^{131} inhalé sous forme de vapeur et 1,6 pour cent du total de I^{131} inhalé sous forme de AgI^{131} 'insoluble'. Cette quantité représente 60 pour cent de la quantité corporelle totale. Chez des moutons, la fixation thyroïdienne maximale se produit entre 20 et 35 heures après inhalation ou administration orale, sous-cutanée ou intrapéritonéale. La quantité de I^{131} inhalé fixée par la thyroïde est de 2 à 7 pour cent, alors qu'elle est de 40 à 60 pour cent pour l'iode administré par les autres voies. Les résultats obtenus avec les particules de AgI^{131} montrent que les liquides organiques ont des propriétés inhabituelles pour solubiliser des particules relativement 'insolubles'.

REFERENCES

BAIR, W. J.: Deposition, retention, translocation, and excretion of radioactive particles *In:* Inhaled particles and vapors. Pergamon Press, Oxford. In press.

BUSTAD, L. K., WARNER, D. E. and KORNBERG, H. A.: Effect of stable iodine on uptake o radioiodine in sheep. Amer. J. vet. Res. 19 (1958), 883.

— GEORGE Jr, L. A., MARKS, S. et coll.: Biological effects of I^{131} continuously administere to sheep. Rad. Res. 6 (1957), 380.

— HERDE, K. E., WARNER, D. E. and KORNBERG, H. A.: Toxicity of I^{131} in sheep. I. Genera (Preliminary report on low-level chronic effects). Hanford Biology Research — Annua Rep. 1951, Document HW-25021 (1952), 139.

DAILEY, M., WENDER, I. and ABRAMS, R.: Tracer studies with inhaled eight-day iodine Terminal Rep. Chicago Univ. metallurg. Lab. Document MDDC-251 (1945).

GUYTON, A. C.: Measurement of the respiratory volumes of laboratory animals. Amer. J Physiol. 150 (1947), 70.

HANDBOOK OF BIOLOGICAL DATA. Edit. by W. S. Spector. Saunders, Philadelphia 1956.

HEALY, J. W., CLARKE, W. J., SEIGNEUR, L. J. et coll.: Early uptake of radioiodine in th thyroid of the sheep. Hanford Biology Research — Annual Rep. 1957, Document HW 53500 (1958), 75.

HERDE, K. WX., WARNER, D. E. and BUSTAD, L. K.: Toxicity of I^{131} in sheep. II. Instrumentation. Hanford Biology Research — Annual Rep. 1951, Document HW-25021 (1952), 160.

Recommendations of the International Commission on Radiological Protection. Report of Committee II on Permissible Dose for Internal Radiation (1959), 193.

SELDERS, A. A. and HUNGATE, F. P.: The foliar sorption of iodine by plants. Hanford Atomic Products Operation Document HW-44890 (1956).

SMITH, G. D. and BAIR, W. J.: Aerosol exposure through a surgically prepared tracheal fistula. Hanford Biology Research — Annual Rep. 1958, Document HW-59500 (1959), 97.

WILLARD, D. H., BAIR, W. J., TEMPLE, L. A. and SMITH, V. H.: Techniques for exposure of mice to aerosols of radioactive particles. Hanford Atomic Products Operation Document HW-52368 (1958).

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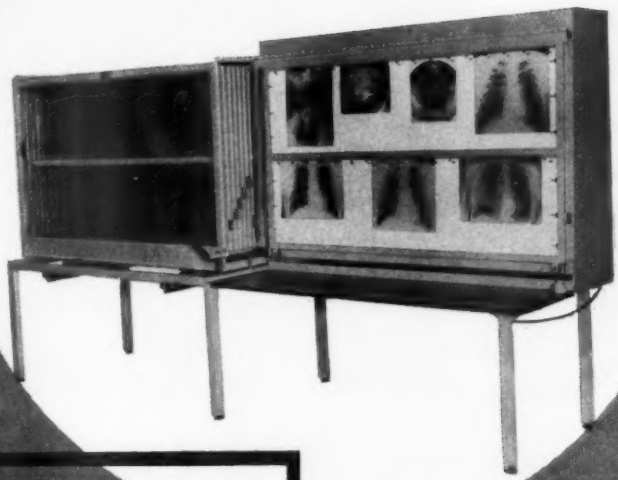

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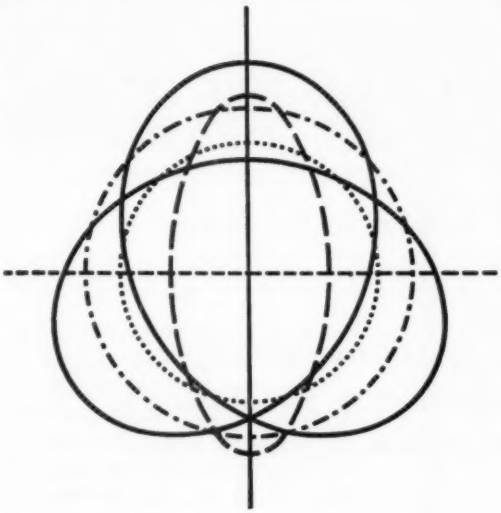

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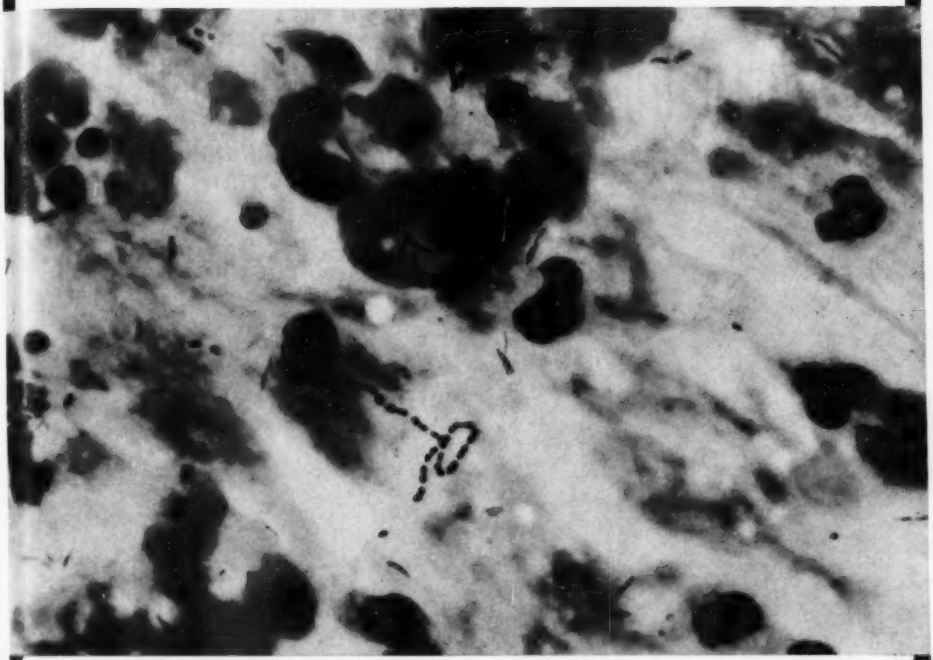

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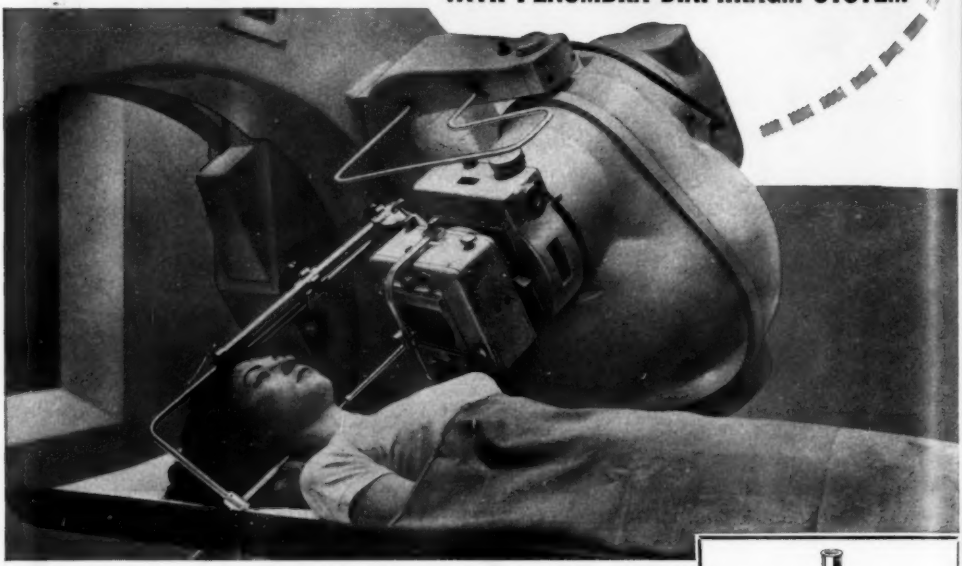

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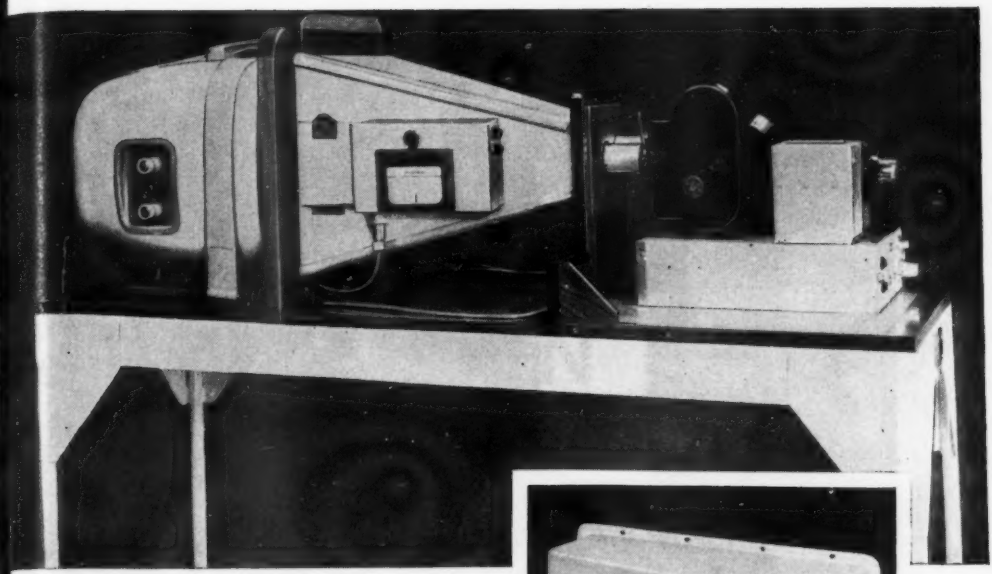

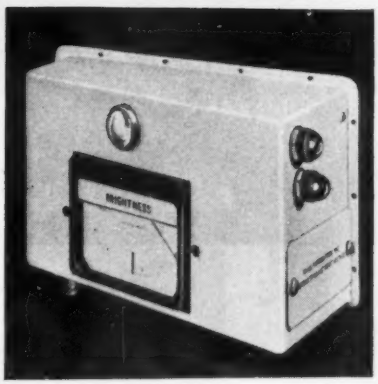

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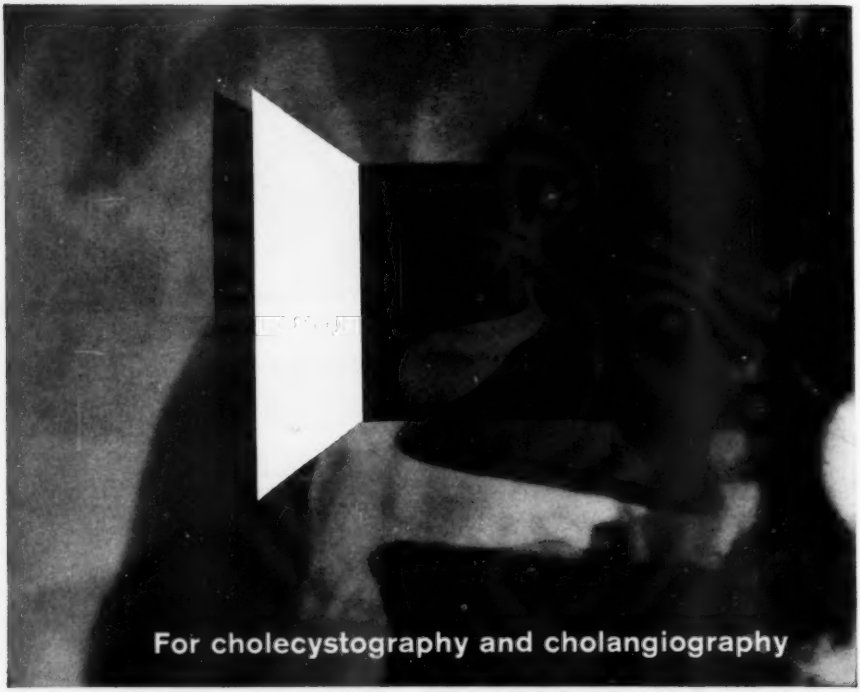

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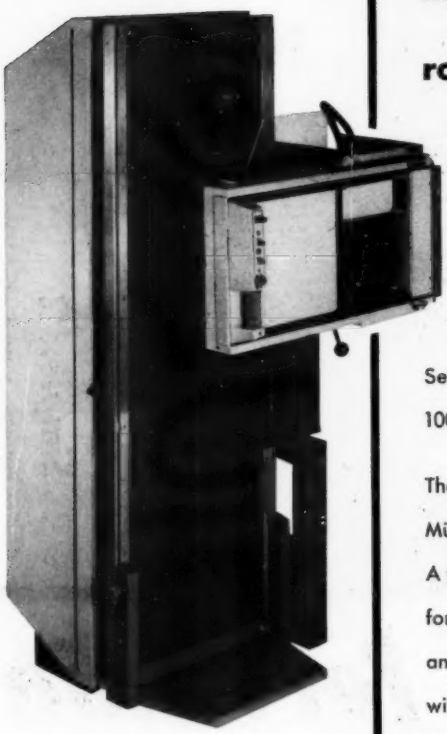

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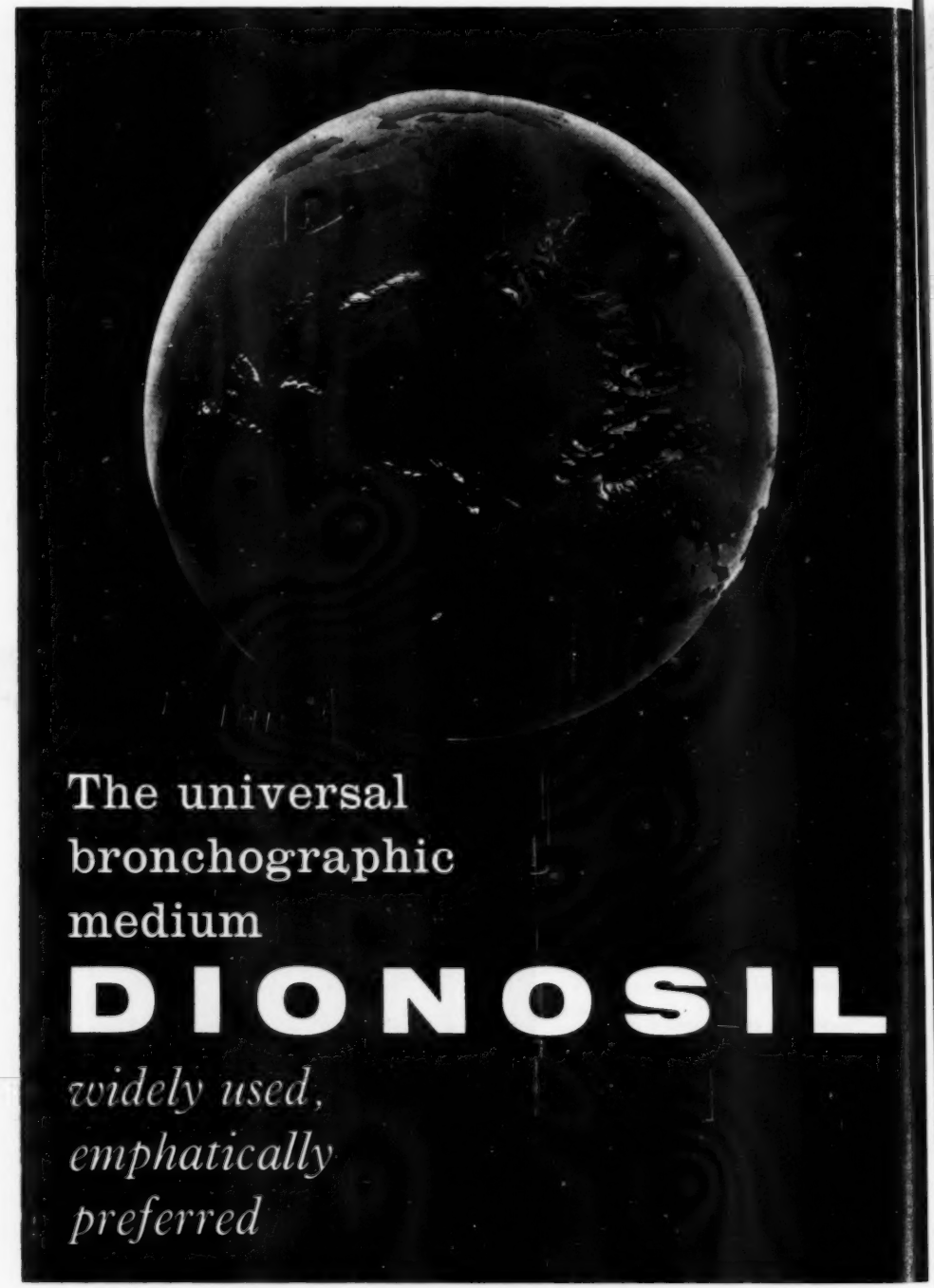
In the motordriven Philips "Alternator" designed on the Paternosterprinciple 20 viewing frames of each 50 × 170 cm (20 × 70 inches) can be moved up and down in front of an illuminating box with fluorescent tubes. As an example can be mentioned that the frames take 360 roentgen films of size 18 × 24 cm (7 × 9 inches).

The movement of the viewing frames can be controlled by the foot which leaves both hands free when hanging the roentgen films.

For quotations ask the nearest PHILIPS roentgen office or direct

SVENSKA AB PHILIPS P.O.B. 6077 STOCKHOLM 6 SWEDEN



Available as oily or aqueous suspensions of propyliodone, in 20 ml vials and in 100 ml bottles

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for cinefluorography...these advances

- extended cinefluorographic film runs, up to three times longer than is possible with any other tube
- superior film definition with the 0.5mm focal spot using grid-controlled, millisecond exposures
- reduced patient dosage through optimum usage of x-ray beam, provided by grid control

for general radiography...these advances

- increased ratings, new focal spot combinations for radiographic and fluoroscopic techniques, to 150PKV
- superior spot film work, to 150PKV, with smaller focal spot size, and fluoroscopy, using ultra-fine focal spot
- higher heat loadings for improved individual examinations and expanded patient schedules
- greater tube maneuverability for under-table techniques

These innovations in design distinguish the Dynamax "50" series:

- Grid control of electron beam permits millisecond exposure; allows use of square wave form for most efficient use of x-ray energy.
- High speed rotation of anode (to 10,000 rpm) provides 70% higher energy ratings than similar sized inserts operated at conventional speeds.
- Highest capacity thermal characteristics:

Anode heat storage capacity	140,000 heat units
Anode cooling rate	40,000 heat units

(Heat unit = PKV x ma x seconds)

Inquiries welcomed . . . engineering consultation is available. Write us today for complete technical data on the significant new Dynamax "50" series.

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THE MACHLETT LABORATORIES, INC.
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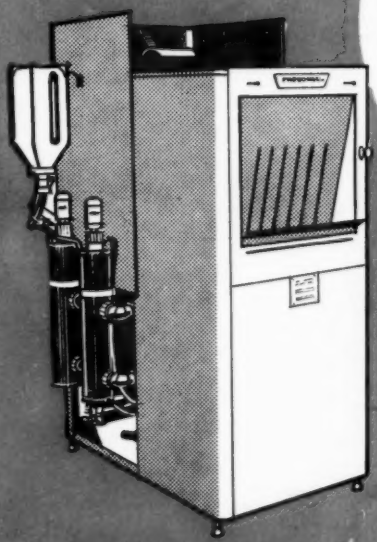
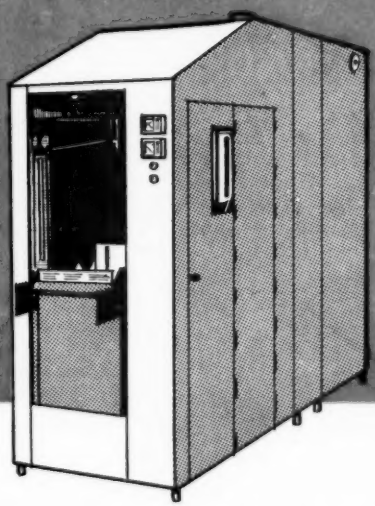
PROCOMAT

automatic film processing machines



PROCOMAT JUNIOR

Drying section excluded.
Processing time 9 min. All film sizes up to 14x17 inches.
About 100 films per hour.



PROCOMAT RAPID

Minimum processing time 7 min.
All film sizes up to 14x17 inches.
About 250 films per hour.

ELEMA-SCHÖNANDER INDUSTRIVÄGEN 23 STOCKHOLM-SOLNA SWEDEN

#730

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